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The Journal of HEREDITY

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A TETRAPLOID FROM AUXIN-TREATED CALLUS TISSUE

Frontispiece

Plant of hybrid tobacco (*Nicotiana sylvestris* × *N. tomentosiformis*) which had been decapitated and the cut stem treated with the plant growth-hormone, hetero-auxin. This forms a callus tissue, from which roots and later leaf shoots are regenerated. A considerable proportion of these regenerated shoots prove to be polyploids. Here are shown a narrow-leaved unbalanced tetraploid shoot on the right (see Figure 6*G*) and on the left a more normal shoot, which may be either diploid or tetraploid.

INDUCTION OF POLYPLOIDY IN NICOTIANA

By Hetero-Auxin Treatment

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THERE are today available to the geneticist a number of methods for inducing polyploidy in plants, foremost among which, by virtue of its general applicability, is the colchicine method, recently described by Blakeslee and Avery,[1] Nebel,[13] and Nebel and Ruttle.[14] At the same time the experiments with colchicine were in progress, we were engaged in efforts to induce polyploidy in Nicotiana by promoting production of callus tissue and shoots by auxiliary agents. The results have been described in a brief preliminary report published elsewhere.[3] The present article contains a detailed account of these experiments.

TETRAPLOID SHOOTS
Figure 1

Tumor-like callus on *Nicotiana tomentosa* (Acomaya,—non-inbred line). Produced by treating a decapitated plant with hetero-auxin. Among the shoots regenerating from the callus tissue several are tetraploid. Note also the young shoot mass in foreground, which will give rise to a new crop of shoots.

Preliminary Experiments

In a search for a substance which would induce callus formation in Nicotiana five different treatments were given decapitated plants of F_1 *sylvestris-tomentosa* and *sylvestris-tomentosiformis*. Table I lists the kinds of treatment and the number of plants treated in each case in this trial series. This work was begun early in April, 1937. In test 1, a thin layer of lanolin paste containing one per cent of indole-3-acetic acid was applied to the cut surface of the stem immediately following decapitation. In test 2, yeast extract of unknown concentration was applied in both full and half strength of the original extract* to decapitated stems through pieces of glass tubing drawn to a narrow diameter at one end and pushed into the surface or laterally into the stem just below the surface. The cut surface was then covered with fluid petrolatum or petroleum jelly. Test 3 served as a check on the indole-3-acetic acid series, and the treatment was the same as that of test 1 except for the elimination of hetero-auxin. In test 4, large vials 9×3 cm. were placed over the cut end of the stem with the object of maintaining a saturated atmosphere over the cut surface. A high humidity was maintained by inserting a moistened cotton plug in the upper end of the vial and proper ventilation was

*Suggested and kindly furnished by Dr. Folke Skoog visiting at the Univ. of California.

RESPONSE OF DECAPITATED STEMS TO HETERO-AUXIN TREATMENT

Figure 2

A—Root development from callus tissue. These roots were grown to a considerable size by culturing in soil in a pot tied to the stem. *B*—A crown of roots developing when the stem was surrounded with wet blotting paper. *C*—Beginnings of shoot production; the large shoot to the left arises from one of the proliferations. *D*—Callus production in F_1 *glutinosa-tomentosa* hybrid. The callus growth is 3 cm. wide and 2 cm. high. The later development of callus shoots is shown in the two lower photographs. *E*—An octoploid shoot in the center, with a young adventitious shoot mass, indicated by the arrow, in front of it. Note also the thalloid-like leaf on the left. *F*—Photograph of end of stem, showing peripheral origin of most shoots, although some shoot masses arise from the pith region; 106 shoots were removed from this plant over a 22-day period.

assured by blowing two small holes above and below on opposite sides of it. Test 5 followed the well-known procedure for inducing polyploidy in the tomato; i.e., decapitation followed by application of a protective covering of petroleum jelly to the cut surface. In all of the above tests the plants were immediately and thoroughly disbudded, and all buds which subsequently developed were promptly removed.

Four of the 12 plants which were given the hetero-auxin treatment in test 1 received seven applications of the hormone paste at three-day intervals, some of the old paste being removed each time. The others were given fewer treatments, but it was later found that one application was sufficient. Too thick a coating does not slough off as the callus develops, but forms a tough, impervious covering inhibiting adventitious bud formation. This was observed only on plants kept in the lathhouse where conditions were relatively moist.

The indole-3-acetic acid treatment was the only method which led to the regular development of callus tissue. The other four treatments gave essentially negative results. The chances of success are, however, apparently somewhat better for the yeast extract and moisture chamber treatments than for lanolin and petroleum jelly, for a few shoot masses were obtained from the former but they could not be definitely assigned as to origin, seemingly arising in the axils of the leaves if the cuts were made through them. In only one instance was a shoot observed to arise in a non-axillary position, and in no case was callus production comparable to that obtained from hetero-auxin treatment. One tetraploid shoot of axillary origin was recorded; it may have been an error or a rare event.

Root shoots were produced abundantly by F_1 *sylvestris-tomentosa* and *sylvestris-tomentosiformis*. A number of them were also examined but they all proved to be normal. It was thought that injury through scraping might induce production of polyploid shoots. Some of the larger roots were laid bare and scraped well with a knife, and the wounded surface was then covered with petroleum jelly. Six plants were treated in this manner and six others prepared in the same way were protected with lanolin. The lower portions of the stems of nine more plants were thoroughly scraped and protected similarly. The plants thus treated suffered a loss in vigor. None of these efforts was successful. Deep wounds were also cut in the axils of the leaves. All but one of such axillary shoots examined were found to be normal. Some polyploids would, however, be expected among a sufficiently large number of such shoots.

As a check on the Nicotiana treatments a more or less parallel experiment was carried out with tomatoes where the results of decapitation experiments are well known. Fourteen decapitated plants of the commercial variety, Sutton's Majestic, were smeared with hetero-auxin paste, 10 with petroleum jelly, and 14 with lanolin. The 14 hetero-auxin treated plants developed large calluses, but no shoots over a period of two to three months. Shoots were, however, produced on the cut stem surfaces which had been treated with lanolin and petroleum jelly, but most of them came from the large axillary calluses developed as a result of continued removal of axillary shoots.

The shoots removed were rooted, and after they had been grown for some time were classified into three groups as follows:

I—266 having only normal leaves.
II— 89 having thalloid-like, much thickened, fleshy leaves.
III— 3 having both normal and thalloid leaves.

Plants of the second group often formed no growing point, but consisted entirely of the abnormal, disproportionately large leaves and roots attached to a tumor-like crown. They constituted 25 per cent of the plants obtained.

Two of them were transplanted into large pots in order to observe what they might do under more favorable conditions. One developed a growing point, which, however, became lost. Normal

...ting, showing peripheral origin of most shoots, although some shoot masses arise from the pith region; 106 shoots were removed from this plant over a 22-day period.

TUFTS OF CALLUS SHOOTS

Figure 3

Tufts of shoots on *N. tomentosa* (Machu Picchu) (*A*), and on *N. glauca* (*B*). The former includes six tetraploid shoots, and a small densely-tomentose octoploid, at *X*. *C*—Callus shoots on F_1 *sylvestris-tomentosa*, illustrating apparent internodal origin of the shoot mass. Of sixteen shoots produced by one such plant, thirteen were tetraploid. *D*—Callus shoot tuft on *N. tomentosa* (Machu Picchu), from which fifty-six shoots were removed at one time. Shortly afterwards a similar crop was ready for removal. On the average about an eighth of these shoots were tetraploids, and about one per cent octoploids.

ORIGIN OF TETRAPLOID

Figure 4

Callus shoots on *N. Tabacum* (Maryland Mammoth) arrow pointing to a tetraploid shoot.

appearing shoots finally arose at several points on the then fasciated stem. Somatic mitoses of root-tip preparations taken from some of the callus shoots showed the 4*n* chromosome number in some of the roots and in one preparation all four roots were tetraploid. Some 2*n* callus tissue was probably removed along with 4*n* shoot tissue, or vice versa, or the shoots themselves may have been chimerical. There were, no doubt, a large number of tetraploids among the 358 shoots grown.

Following the discovery that hetero-auxin would induce callus and shoot formation in F_1 *sylvestris-tomentosa* and *sylvestris-tomentosiformis*, 113 of these plants were decapitated and treated. Most of the following results were obtained from these plants, about 100 of which were treated twice.

Response of Nicotiana Hybrids to Hetero-auxin Treatment

Decapitated stems first show circumferential swelling and the pith protrudes. This increased diameter of the cut surface is due to the initiation of root primordia and to their development, for in time the periphery may become quite swollen and bumpy. In some instances roots push directly through the cortex, giving the appearance of curling this zone before them as they break through. If the necessary moisture is provided hundreds of the short stubby protuberances may develop into well-formed roots (Figure 2*A*, *B*); if not, they become merged with the rest of the callus tissue. The cut surface also shows a marked growth response. Protuberances may form over the entire surface which then becomes warty, crevassed, and finally covered by a brown, corky layer, underlain by green cells. A longisection through a well-developed callus exhibited a newly-formed cambium over the entire wound surface. The regenerating surface may attain great width (two to three times the diameter of the stem at some points), but it is confined to a short vertical zone, indicating the localized effect of the hormone (Figure 2*D*, Figure 1). The changes described are usually completed about 4-6 weeks from the time of decapitation. If the plants are decapitated in the spring shoots begin to appear about six weeks after treatment.

Production of Callus Shoots

Shoots may arise anywhere on the callus surface, but the majority have a peripheral origin. The accompanying photographs illustrate not only features connected with the production of callus shoots, but also some of the different kinds of shoots which are obtained. Figure 2*C* shows a shoot arising directly from one of the root-like protuberances. Figure 2*E* shows a short, thick, fleshy octoploid shoot arising from the pith region, while the rest of the shoots are mainly peripheral. It also illustrates the development of thalloid-like leaves, often lacking or failing to develop a growing point, and the enormous growth of callus tissue. Figure 2*F* illustrates the immense number of shoots which may arise from a single callus. The large numbers are more readily seen at an earlier stage when the adventitious shoots are mere

specks. As many as 110 shoots have been removed from a single callus over a period of 22 days. In addition to normal and polyploid shoots, a number of teratological adventitious growths have been observed, such as pitcher leaves, and leaves with four half-blades grown to one midrib, some of which produced buds at one or more points along the midrib. Dense tufts of shoots arise in many instances (Figures 1, 2*F*, and 3).

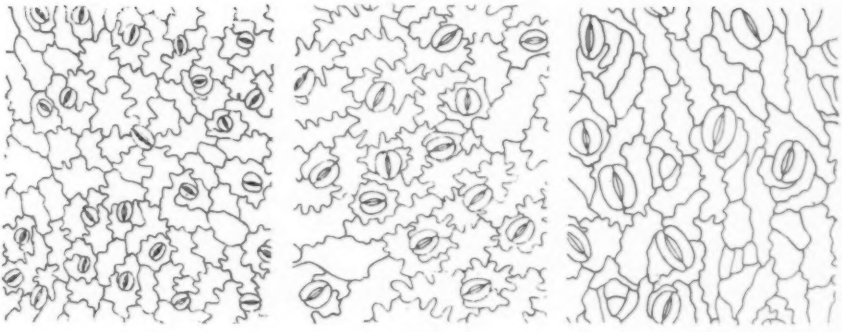
The shoots are usually removed from the callus when about 2-3 inches long and rooted in sand. New shoots continually appear in large numbers and harvests must be made about every two weeks.

This method depends for much of its success upon the good condition of the plants used. The more vigorous the plants, the better are the chances to obtain a large number of callus shoots, and the longer will be the life of the decapitated plants. Disbudding, regular watering, and some good fertilizer at frequent intervals would seem to be absolutely necessary for best results. The plants also must not be crowded. Finally, the hormone-treated surface must be protected from too strong sunlight until shoots appear, otherwise neither callus tissue nor shoots develop. This is easily done with a manila paper bag, or with cheesecloth. Plants which produced no shoots in the intense sunlight of summer produced them belatedly when brought into a whitewashed greenhouse. Light must later be admitted commensurate with the needs of the shoots formed.

The Frequency of Different Kinds of Shoots

For the determination of the frequency of occurrence of tetraploids, 1,173 plants, an approximately random sample, were grown in pots for 2-3 months before they were counted and classified. Among larger plants tetraploids can be expected to be detected more readily than among shoots 3-4 inches long, especially if one is not familiar with the type. In this lot of 1,173 plants, 270 were tetraploid. This does not include 800 normal shoots eliminated directly from the cutting flats by examination of the stomata. The frequency of 4*n* shoots is therefore 13.7 per cent. This figure may be somewhat low. Single plants grown in the field have produced as high as 50% or more of tetraploid shoots, but this is exceptional and applies only to single harvests. Some 30 shoots, or about 1% were octoploid. In addition to the polyploids, shoots with unbalanced chromosome complements were occasionally produced (Frontispiece). Five such plants, all different, are at present available. Table II lists the number of tetraploids obtained from single plants of F_1 *sylvestris-tomentosa* and *sylvestris-tomentosiformis*, as compiled from a recent census. It is evident from the table that relatively few plants suffice to insure production of tetraploids, since of the total of 125 plants treated, 19 of which were discarded for various reasons, such as death from disease, failing to produce callus tissue and shoots, preference for the better plants in making selections, etc., 101 of the remaining 106 produced one or more tetraploid shoots. A total of 388 amphidiploids is recorded. No multiplications from cuttings are included in the data.

The figures in Table III, representing results from field-grown plants, are further proof of the high frequency of occurrence of polyploids. The classification of these shoots was based mostly on stomatal examinations made in the field, supplemented by morphological criteria. All of the counts were of single harvests. The counts made on F_1 *sylvestris-tomentosa* were for the most part of large, well-formed shoots among which tetraploids are readily detected. Since these counts were made following observation of some 2,000 similar shoots in the greenhouse, errors are scarcely probable. It is to be noted that little or no selection for polyploid shoots was practiced before these shoots were removed and classified. The remainder of the determinations are less accurate, but on the whole probably correct. Naturally it must be realized that a number of these shoots have a common origin on the callus surface.



A B C

STOMATA AN INDEX OF POLYPLOIDY

Figure 5

Stomata and epidermal cells of F_1 *sylvestris-tomentosiformis*. *A*—Diploid; *B*—Tetraploid; *C*—Octoploid (from F_1 *sylvestris-tomentosa*). All drawn to the same scale, about 180×.

Morphological Comparison of the Diploid and Polyploid Types

The two F_1 hybrids (*sylvestris-tomentosa* and *sylvestris-tomentosiformis*) are similar in general features and can be discussed together. They are large, extremely vigorous plants, attaining a stem diameter of about 2-3 inches and a height of 12 feet or more when grown in the field. The leaves of both are oval-acute with a length : width ratio of 1 :1.9. The leaves are undulate at the margin, thin, with venation not prominent; they do not show the well-defined pattern along the margin found in the amphidiploids. The glandular-capitate hairs are small, and the stomata and cells are small (Figure 5*A*). F_1 *sylvestris-tomentosiformis* is of a lighter green than F_1 *sylvestris-tomentosa*, and it also is less tomentose. There is no buckling of the leaf tissue between veins such as is found in the amphidiploids. F_1 *sylvestris-tomentosiformis* comes into flower about two or three weeks earlier than *sylvestris-tomentosa*.

The tetraploids prove to be as large as the F_1 hybrids and may even surpass them in size. The overall dimensions of their flowers are also greater. The leaves are wavy-margined, ovate-cuspidate, i.e. with a short, sharp tip. Their length: breadth ratio is 1:1.6; hence they are distinctly broader proportionally than those of the diploids. The stomata and cells (Figure 5*B*), as well as the glandular-capitate hairs, are larger. The venation is coarser and inclined to be slightly fasciated. The leaf tissue also is slightly buckled between the veins, resulting in a characteristic leaf pattern. The color differences as well as the degree of hairiness of the parents are maintained in the amphidiploids. The tetraploids exhibit differences in time of flowering similar to those of the diploids. The octoploid *sylvestris-tomentosa* has uniformly thick, fleshy stems (Figure 7*A-B*). Its leaves are small, numerous, fleshy, thick, stiff, lacerate-sinuate and contorted, often with variegated areas (Figure 7), and fasciated venation. Its cells and stomata are exceedingly large (Figure 5*C*), surpassing expectation based on the diploid-tetraploid relationship. It is very slow growing. It is very glutinous, with very large glandular-papillate hairs which are often branched three or more times. The octoploid *sylvestris-tomentosiformis* is similar to the above, but it appears to be even more monstrous and is perhaps nearer the limit of viability as evidenced by the dying leaf tips (Figure 7*C*). One of these shoots, however, obtained from a tetraploid callus this spring has now developed buds and flow-

ers. Its flowers are distinctly smaller even than those of the corresponding diploid, with the limb of the corolla much reduced and more irregular. The tube is also shorter, but thicker than in the diploid, and the anthers, though larger, are malformed, with the two locules unequally developed. The leaves of the plant shown in Figure 7*C* are mostly midrib; they are malformed, contorted, and turned downward. The apical bud consists of small, closely imbricated woolly leaves. It is the slower growing of the two octoploids. The behavior of octoploids, viz. dying of leaf tips and rate of growth seems to vary with the season; the behavior described is that observed during late summer and fall. Experimentally produced octoploids in higher plants have only been reported elsewhere for Brassica, by Shchavinskaya.[10*]

Chromosome Numbers

The diploid chromosome number of both hybrids is 24. In F_1 *sylvestris-tomentosa* three cells each with 24 chromosomes were counted (Figure 6*A*). Figure 6*B* shows a tetraploid complement of the amphidiploid *sylvestris-tomentosiformis*, with ± 48 chromosomes. Cells allowing accurate counts of these high numbers are necessarily rare. Figure 6*C* shows the tetraploid complement with 48 chromosomes of the amphidiploid *sylvestris-tomentosa*. In another plant of the same amphidiploid, four cells each with 48 chromosomes were also counted. The octoploids show 96 chromosomes (Figure 6*D*). Three such cells were counted in root tips of octoploid *sylvestris-tomentosa*, and one in those of octoploid *sylvestris-tomentosiformis*. In the first hybrid 96 chromosomes were counted in one cell (Figure 8*D*), 95 with a doubtful 96th in a second, and 97 in a third. In octoploid *sylvestris-tomentosiformis* 96 ± 1 or ± 2 chromosomes were counted.

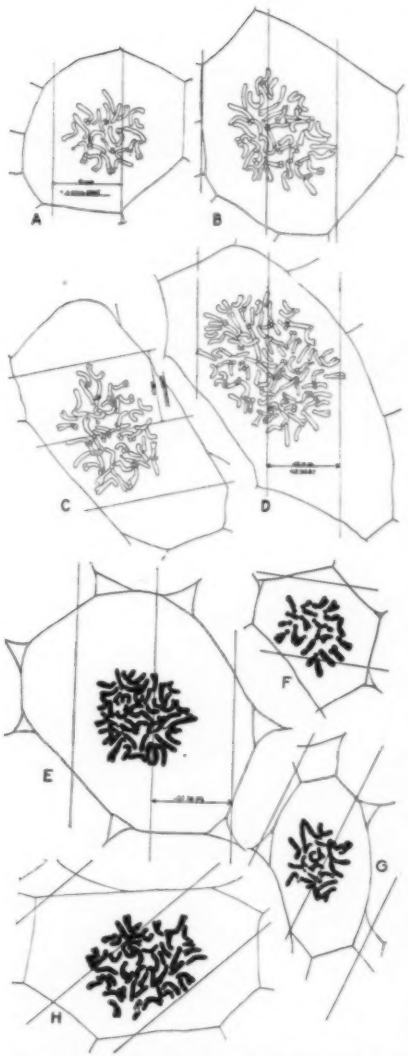
Figure 6*E* shows a plate with 48 chromosomes of *Nicotiana tomentosa* (Acomaya). Figure 6*F* shows one with 23 chromosomes of a narrow-leaved callus shoot from *N. sylvestris-tomentosa*. Occasional cells like this one have the chromosomes much condensed. The plate shown is ideal for counting, and the constrictions are well marked. Fig. 6*G* shows a plate from a narrow-leaved callus shoot of *sylvestris-tomentosiformis*, with probably 23 chromosomes, and Figure 6*H* shows the complement from a narrow-leaved modified tetraploid callus shoot with ± 47 chromosomes. This is the shoot shown in Frontispiece. Not all chromosomally unbalanced callus shoots, however, have the leaves as strikingly modified as this.

All root tips from which counts were made came directly from stem or leaf cuttings of the plants in question. Entire roots were always found to be of the same constitution, and no deviation from the expected number of chromosomes was observed at any time in any of the root tips examined.

Identification of Polyploid Shoots

In general it is advisable to examine shoots when they are 3-4 inches long, or less. Polyploid shoots may thus be removed early from competition and given a good start. The size of stomata is a valuable criterion for their detection. The diploids have the smallest stomata, which, taken together with their relatively narrower, longer, thinner, and less tomentose leaves will readily identify them. Their general high frequency of occurrence will also be an indication of their nature. The tetraploids are identified by the contrary features. Octoploid and other shoots are readily identified by their monstrous aspect alone. Their thalloid, thick, fleshy and laceratesinuate leaves mark them clearly as high polyploids. Table IV gives some stomatal measurements of 8*n* shoots. The stomata of narrow-leaved or otherwise altered forms may approach those of the diploids or tetraploids in size, indicating respectively their probable unbalanced diploid or tetraploid nature.

*I have, however, been reliably informed recently that L. F. Randolph has produced *octoploids* zygotically in *Zea Mays*. Octoploid *tissues* have been reported by Blakeslee and Avery.[1]



SOMATIC MITOSES FROM ROOT TIPS OF ROOTED CALLUS SHOOTS

Figure 6

A—F_1 *sylvestris-tomentosa*, diploid, 24 chromosomes; *B*—F_1 *sylvestris-tomentosiformis*, tetraploid ± 48 chromosomes; *C*—F_1 *sylvestris-tomentosa*, 4*n*, 48 chromosomes; *D*—F_1 *sylvestris-tomentosa*, octoploid, 96 chromosomes; *E*—*N. tomentosa* (Acomaya), tetraploid, 48 chromosomes; *F*—*N. sylvestris-tomentosa* unbalanced, narrow-leaved type, with 23 chromosomes; occasional cells like this one have the chromosomes much condensed; *G*—*N. sylvestris-tomentosiformis*, unbalanced, narrow-leaved form, probably with 23 chromosomes; *H*—*N. sylvestris-tomentosiformis*, unbalanced tetraploid with very narrow leaves (see Frontispiece), with ± 47 chromosomes. The parallel lines are 10 microns apart.

Meiotic Behavior of Diploids and Tetraploids

The hybrid nature of the diploids is clearly evident from an examination of microsporocytes. A few bivalents are often observed, and they are seen stretched across the cell plate, taking a central position in the spindle. The univalents are distributed apparently at random; two major groups are usually seen toward the two poles, with the bivalents stretched between them. Difficulty in separation is evident in the three-partite structure of some of the bivalents. The chromatin between the spindle fiber insertions and the chiasma is often drawn out to a thin thread giving what is apparently an atypical chromatin bridge without fragments. Microsporocytes are frequently produced and the pollen is 99.5% (*sylvestris-tomentosiformis*) or more aborted, the remainder consisting of unreduced, giant pollen grains. Both F_1 hybrids have so far proved completely sterile.

Contrasting sharply with this behavior is that of the two amphidiploids. Microsporocytes present a far more regular picture, with all the chromosomes lying more nearly in one plane on the metaphase plate. Twenty-four bodies were actually counted in tetraploid *sylvestris-tomentosiformis* at this stage. Chromosome behavior is quite regular, and in most cells (*sylvestris-tomentosiformis*) there are about 22-24 bivalents, but no detailed study of the regularity of bivalent formation and distribution has yet been made. Few or no chromatin bridges are formed at meiosis. The pollen was found to be about 85% good. This has been borne out in a number of crosses of *N. sylvestris-tomentosiformis* with *N. Tabacum*, and *N. sylvestris*. Progeny from crosses with haplo-F and haplo-G *Tabacum* are very uniform, and clearly fall into the two expected cate-

gories of haplo type and normal plants. The percentages of germination after six days for the two latter crosses were 83.9% (106 seeds) and 85% (107 seeds) respectively. Germination had occurred after four days. Most seeds from the cross with *N. sylvestris* do not germinate, in accordance with the known effect of the endosperm on the embryo in such a cross. The behavior of the amphidiploid *sylvestris-tomentosa* is similar to that described for *sylvestris-tomentosiformis*, but less data are available for it.

Discussion

The discovery of the decapitation-callus method was made in 1916 by Winkler.[21] It was the result of his attempts to produce graft hybrids or burdos in the genus Solanum. The discovery was an important one, for no other methods for producing tetraploids experimentally were known at that time. The method was subsequently developed by Jorgensen (1928), and employed for various purposes by Lindstrom and Koos[10], Sansome[18] and others, all working with the tomato which appears to respond much more readily to the treatment than most other plants.

The method has also been used with varying success by Petrov[15] on the potato, poplar and Pelargonium, by Shchavinskaya[19,20] on head cabbage, by Pratasenja[17], Povolocko,[16] and Greenleaf[3] on Nicotiana. Among plants so treated which have failed to develop callus and shoots are the potato, *Pelargonium roscum* (Petrov) and Nicotiana. Partial failure has been recorded for *Brassica oleracea* var. *capitata* where only about 27 per cent of decapitated plants developed callus and shoots. Here also may be included the work of Pratasenja[17] who obtained shoots from wound callus at the base of cuttings of leaves and stems in *Nicotiana glauca, N. Tabacum*, a *Tabacum-rustica* hybrid, *Prunus cerasus, Ocimum canum, O. gratissimum* (*Labiatae*), *Cynanchum acutum* (*Asclepiadaceae*) and *Atropa* (*Solanaceae*). No doubt the method has been applied in numerous other instances, but no further successes have been reported.

In all plants in which the decapitation-callus method has been used successfully with exception of the tomato, the percentage of tetraploids has been low, only about 1-2 per cent. Petrov[15] found no polyploids among 327 cytologically examined shoots of the poplar. Karpechenko[5] reported that only about one per cent of shoots produced by F_1 *Brassica-oleracea* var. *capitata* (4*n*) -*B. carinata* (2*n*) had the doubled chromosome number. In the tomato, on the contrary, Sansome[18] found about six per cent and Jorgensen[7] about ten per cent of callus shoots tetraploid. Lindstrom and Koos obtained 32 per cent of diploids from haploids, and 36 per cent of tetraploids from diploids. The reason for these differences within the tomato is not clear, but it may be related to the abundance of callus tissue produced.

Povolocko[16] secured regeneration in Nicotiana by inserting pollinia of tropical orchids into the split stems of decapitated plants. He ascribed their action to their high phytohormone content, which had already been demonstrated by Fitting.[2] Although the use of hetero-auxin in lanolin appears to be a logical improvement of the method employed by Povolocko, his results were unknown to me at the time these experiments were started. A number of investigators had also shown previously that hetero-auxin under certain conditions may stimulate growth and lead to production of callus tissue, but these investigations had not been directed towards production of polyploidy. The species and species hybrids for which the present method has proved highly successful i.e. having formed abundant callus and many polyploid shoots are *N. sylvestris, N. sylvestris-tomentosa, N. sylvestris-tomentosiformis, N. tomentosa* (4 non-inbred lines) and *N. glauca*. Those which responded satisfactorily under favorable conditions in the field are *N. Tabacum* (Maryland mammoth), *N. Tabacum* (*purpurea* and *purpurea Mammoth*); here also should be included the inbred lines of *N. tomentosa* and *N. tomentosiformis* which developed some callus tissue and shoots but were not comparable in their response to the heterozygous

OCTOPLOIDS FROM CALLUS SHOOTS
Figure 7

An octoploid shoot of F_1 *sylvestris-tomentosa* as seen from the side (*A*) and from above (*B*). Note the variant area, marked *x* in the lower photograph. *C*—An octoploid shoot of F_1 *sylvestris-tomentosiformis*, illustrating the monstrous character of such shoots and dying-back of leaf tips. At *D* is shown an old callus from such a *sylvestris-tomentosiformis* hybrid. The small shoot on the left appears to be an octoploid. There is a narrow-leaved form in the foreground to the right, and some diploid or tetraploid shoots behind it.

lines, and *N. sylvestris-glutinosa*. *N. rustica* var. *humilis* has produced very few shoots. Those which have failed to produce callus shoots are *N. rustica* var. *humilis*, *N. undulata*, and *N. paniculata*. Although the number of plants of each of these three species tested was small, failure to respond is clearly indicated. This may be connected with the lesser vigor and shorter life cycle of these plants. Further experimentation is needed to determine the range of applicability of the present method, and the value of other supplementary substances.*

*When shoot production is difficult I find that the upper 2-3 leaf axils thoroughly scraped and treated as in test 1 (p. 451) may produce shoots more readily than an apical callus.

Origin of Tetraploid Cells

Several views on the origin of tetraploid cells in the callus tissue have been presented by different authors. Winkler[21] proposed three ways of their origin. One view is that they are fusion products of two cells and their nuclei, due to the mechanical stress in graft unions, and he presented some evidence for the migration of nuclei into adjacent cells. Secondly, he thought the binucleate cells might already have been present in the stem tissues, and that they became involved in regeneration, and he pointed out that polyploid cells or even tissues regularly occur in some plants. Thirdly, binucleate cells might arise under the influence of the wound stimulus. Winkler himself favored the first view, for he had observed tetraploid shoots only on graft unions. Jorgensen,[7] however, demonstrated that production of tetraploids is not restricted to graft unions and hence supported the second view. In order to explain the union of the two chromosome complements in binucleate cells he hypothecated the process of endoduplication. This explanation does not, however, as Mather[11] pointed out solve the question of the origin of binucleate cells. Mather takes the third, more logical view, for which he presents some evidence. According to this view large, deep-seated, already well-differentiated cells are forced into meristematic activity under the influence of the wound stimulus and nuclear division is not followed by wall formation. The two nuclei thus formed then may fuse some time during the next mitosis. This is a logical explanation of the origin of binucleate cells, but it may also be possible that the two chromosome groups have never been separated completely but gave rise to a single tetraploid nucleus. The origin of $8n$ shoots in Nicotiana requires special consideration. According to the view accepted, octoploid cells would simply arise by a repetition of the doubling process in the same cell or in subsequent cell generations, with the reservation that tetraploid and octoploid nuclei may arise directly from diploid and tetraploid nuclei respectively through a restitution process analogous to non-reduction in meiosis.

It should perhaps be pointed out to the practical plant breeder that homozygous tetraploids should be obtained by doubling the chromosomes of homozygous diploids and not by inbreeding heterozygous tetraploids. On the assumption of random chromosome distribution a duplex tetraploid selfed produces only two homozygotes in 36 after one generation of selfing. With random chromatid distribution a somewhat higher proportion, viz. 9 in 49 will be homozygous after one generation of selfing. In the case of complete dominance which would preclude distinction between simplex, duplex, triplex and quadriplex plants the isolation of a homozygous dominant in such a population would be extremely laborious, and could at best be accomplished in F_4 (by crossing to the homozygous recessive). In order to have an even chance of including such a homozygote among the group of F_2 plants selected progenies of about 18 plants would have to be grown. Depending on what we might consider to be reasonable chances of success we would have to grow correspondingly larger numbers. In practice, therefore, it becomes almost impossible to isolate such a type. Nor would we fare much better if the factor in question approached random chromatid distribution. The general expression for the proportion of heterozygotes after n generations of inbreeding with random chromosome distribution has been given by Haldane.[4]

$$2q_n + r_n = \frac{7}{5}\left(\frac{5}{6}\right)^n - \left(\frac{1}{6}\right)^n$$

where $2q_n$ and r_n are the three heterozygous classes among the progeny of a duplex tetraploid. The corresponding expression for random chromatid distribution is:

$$2q_n + r_n = \frac{98}{65}\left(\frac{77}{98}\right)^n - \frac{98}{65}\left(\frac{6}{49}\right)^n$$

Table V gives the proportion of single factor homozygotes for diploids and tetraploids with random chromosome and chromatid distribution. The values for the triplex are identical with those

given for the simplex. These values represent extremes of expectation of homozygosis. The actual value will always lie between these limits. Mather[12] in a masterly exposition shows that random chromatid distribution will only obtain when: 1. pairing of the four chromosomes at zygotene is random; 2. when the chiasma frequency between the insertion and the locus of the factor is infinite; and 3. when disjunction of the four chromosomes of the tetravalent is random. Under these conditions 1/7 of the separations at each locus are reductional and 6/7 are equational, resulting in the gametic series: $3AA : 8Aa : 3aa$. As Mather has also shown in detail this behavior is aided by a variation in chiasma frequency in the section between the insertion and the factor. Hence in practice some factors give segregation ratios which closely approach, but never quite attain that expected from random chromatid segregation.

I wish to acknowledge my obligations to Dr. R. E. Clausen for his exceedingly valuable advice and suggestions, to Mr. E. R. Dempster for indispensable aid in Mathematics and Mr. P. C. Burrell for advice in cytological technique.

Summary

Experimental means for inducing polyploidy by regeneration of decapitated stems were reviewed and tested. It was found that by the use of hetero-auxin (indole-3-acetic acid) plants of several species and species hybrids in Nicotiana could be made to regenerate beautifully. Two F_1 hybrids in particular have been used in these experiments: *Nicotiana sylvestris-tomentosiformis* and *N. sylvestris-tomentosa*. Enormous calluses have been formed in many instances and hundreds of shoots were obtained from them. These plants did not regenerate without application of the hetero-auxin. It was also found that the treatment resulting in the formation of shoots in Nicotiana inhibited their formation on callus of tomato plants. From 1,973 classified shoots of the two F_1 hybrids mentioned, the frequency of occurrence of tetraploid shoots was found to be 13.7 per cent. About 30 octoploid and five different heteroploid shoots have also occurred. Of considerable interest in these latter types is the relation of the chromosome numbers to the morphological features exhibited by these plants. The allo-octoploid types with 96 chromosomes show great deviation in morphology as compared with the corresponding diploids and tetraploids. A general decrease in size of the plant body is correlated with general monstrosity in the $8n$

TABLE I. Types of treatment applied in preliminary tests for production of callus tissue.

Test No.	No. of plants	Type of treatment
1	12	Indole-3-acetic acid in anhydrous lanolin (2%).
2	6	Yeast extract
3	42	anhydrous lanolin
4	8	moisture chamber
5	84	Petroleum jelly

TABLE II. Number of tetraploid shoots obtained from each mother plant of the two F_1 hybrids.

Hybrid	Number of tetraploid shoots															Total Plants	Total Shoots
	0	1	2	3	4	5	6	7	9	10	12	14	15				
N. sylvestris-tomentosiformis	2	9	9	3	2	2	2	1	-	1	-	1	-			35	97
N. sylvestris-tomentosa	-	25	13	6	5	4	4	5	1	6	2	-	2			71	891

TABLE III. Counts of single harvests with recorded number of tetraploid 4n shoots found on single plants of species and species hybrids of Nicotiana.

Species and Hybrids	Total shoots per plant	Number 4n
N. Tabacum var. Maryland Mammoth	* 11	4
" Hybrid	* 41	5
N. tomentosa (non-inbred line)	33	4
	14	3
	56	0
	33	0
	23	7
	5	2-3
N. sylvestris-tomentosa F_1	13	3
	14	0
	16	11
	24	15

* ca. 3-5 plants provided the shoots.

TABLE IV. Comparative sizes of stomata of diploid, tetraploid and octoploid types. Each value is the mean of 50 length measurements (eye piece micrometer units).

Species hybrid		Age of leaf	Length: width	Number of samples from same slide.	Length of stomata
N. sylvestris-tomentosiformis	2n	young	19:9	3	13.8±1.4 13.3±1.2
		mature	20:10	3	14.6±1.6 13.9±1.2
		prime		1	14.7 ± .13 13.0 ± .13
	4n	young	18:9.5	2	19.1±1.8 18.6±2.0
		mature	20:7	2	20.4±1.0 19.7±1.1
		—	—	3	19.9 ± .33 19.8 ± .45
	8n	-	-	1	21.1±1.0
N. sylvestris-tomentosa	8n	-	-	1	24.3±1.1
		-	-	1	23.9 ± .28

TABLE V. Proportion of single factor homozygotes after selfing in the diploid, and in simplex and duplex tetraploids.

Random chromosome segregation				Random chromatid segregation		
generations selfed	diploid Aa	Tetraploid Aaaa	Aaaa	Tetraploid Aaaa	Aaaa	
1	.5	.25	.02	.2083	.0918	
2	.75	.36	.194	.4496	.4714	
3	.875	.4021	.3256	.5696	.4457	
4	.9375	.8779	.4375	.6614	.5486	
5	.96875	.8483	.5313	.7339	.6483	

plants. The changes go beyond the usual quantitative deviations from the parental form observed in polyploids in general. The theoretical behavior of tetraploids upon inbreeding has been considered on the basis of random chromosome and chromatid segregation in the simplex, duplex, and triplex, and the expected proportions of homozygosis calculated up to five generations.

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THE GENETICS CONGRESS

THE Organizing Committee promises an early announcement of the preliminary program of Congress. A list of prospective papers to be delivered at the Congress has been received. From this it appears that much good sound genetic provender will be served by Chief Chef Crew August 24-30 next.

The announcement of the American Travel Committee regarding Congress tours follows:

Continental Tours

These may be arranged through Messrs. Allen and Harms either on the basis of transportation alone, or on an all-inclusive basis. For four sample routes, likely to interest geneticists, beginning and ending at ports for which through rates from North America are available, we give approximate prices of transportation only.

A. Oslo-Stockholm-Svalof-Lund-Copenhagen-Berlin-Leipzig-Prague-Brno-Vienna-Munich-Zurich-Basel-Cologne-Wageningen-Amsterdam-Rotterdam.

Second Class	Third
$70.00	$40.00

B. Stockholm-Lund-Svalof-Copenhagen-Berlin-Munich-Zurich-Paris-Boulogne.

Second Class	Third
$59.00	$40.00

C. Copenhagen-Hamburg-Groningen-Arnhem-

(*Continued on page* 466)

THE ORIGIN OF LIFE

A Review

ESSENTIALLY this is a book* on chemical evolution. Organic (biological) evolutionary concepts are logically pressed into service in the inanimate world of chemical compounds including the proteins, collodial complexes and enzymes. The author, I. A. Oparin, is listed as an associate director of the Biochemical Institute of the U.S.S.R. Academy of Science, Moscow. The translation with annotations is by Sergius Morgulis, Professor of Biochemitsry, University of Nebraska, College of Medicine, Omaha. A bibliography is appended, giving American readers a splendid source of many European, especially Russian, works which might well have been overlooked. An author and a subject index are included.

Woven throughout this brilliant book of 270 pages is an unusually clear thread of modern biochemistry, at once an excellent review for advanced students in the sense of providing a refreshingly new outlook; and yet so simply written that biologists may well grasp many of the biochemical essentials of their science. The philosopher or even the layman will sense the logic and reasonableness of this story of chemical evolution, so lucidly is it expressed.

The author begins by disposing of several older hypotheses of life's origin. After a brief survey of "spontaneous generation" hypotheses, he categorically rejects them on the basis of the impossible chance that life's unbelievably complex aggregation could have arisen fortuitously. Likewise does he dismiss the possibility of life coming from other worlds, because of time and space difficulties as well as of the lethal action of ultra violet from the stars and of cosmic radiations in interstellar space where no protection of the atmosphere is afforded any living organism.

While he commences his real story with the elementary transformations of chemical substances when the earth separated as a molten mass from the sun, the really new and carefully reasoned parts begin at the stage when complex organic compounds have emerged. Step by step he carries the complexity further, utilizing largely the familiar biological concepts of reproduction and natural selection, whereby successful complexity survives and carries on; all else disintegrates.

Beginning with organic compounds and the proteins, he pictures these as present in the waters of archaic seas and oceans in the form of colloidal solutions, their molecules dispersed in this aqueous solvent. But as the colloidal mixtures of unnumbered compounds were shuffled about by mere chance, new and unique formations occasionally emerged, some of which were the semiliquid colloidal gels or "coazervates" as the author calls them. These colloidal droplets become separated from the solvent medium (their external environment) by the beginnings of a distinct membrane formed by adsorbed molecules of water. In this membrane of hydration water, the innermost water molecules are firmly attached, and strictly oriented with regard to each other.

This is a most important milepost on the road to life because it insures the beginning of a specific individuality of the droplet (coazervate), one in which this primitive system is more or less sharply differentiated from its external environment, a significant characteristic of living things. Future success is now determined not only by its own specific internal makeup but also by its reaction to the external medium. Those droplets possessing a structure capable of growth and reproduction in kind, survived in the

*OPARIN, I. A. *The Origin of Life.* Translation from Russian by Sergius Morgulis. VIII + 270 pp. Bibliography and index. The Macmillan Co. 1938.

process of natural selection, all others distintegrated.

The ability to divide endowed the coazverate droplet with a definite advantage in the matter of future persistence. Such division and reproduction would not only increase the mass of this organized substance but, what is more important, would permit new changes to arise in definite directions. These changes in turn, if adapted to conditions, and if capable of reproduction, would persist.

This evolution towards complexity would be speeded up greatly if the velocity of chemical processes could be increased. Organic substances utilize their chemical potentialities very sluggishly. It is for this reason that the organic chemist resorts to powerful reagents and extreme conditions to accelerate syntheses. In living cells, chemical reactions ordinarily take place with very great speed by virtue of catalyzers called enzymes. At this point the author develops his ideas on the uature, complexity and interactions of known enzymatic processes. He then proceeds to reason that such perfect, smooth-working complexes could only have arisen by a definite direction of evolutionary steps whereby natural selection would destroy unsuccessful combinations, allowing those to continue which would fulfill their function with the greatest celerity and efficiency.

Only those coazverates were successful in the growth competition whose structure had undergone profound changes to provide a suitable enzymatic apparatus. In time the coordination of enzymatic processes became more and more perfected insuring a high degree of functional stability. Here we are at the threshold of life as we now know it. Chapter 7 on the origin of primary organisms is the high point of the book.

In the last chapter on the continued evolution of primary organisms, the author ends with a consideration of further refinements of the inner physiochemical apparatus of the organism. The birth of new substances such as pigments, including chlorophyll, and the beginnings of respiration and fermentation processes are classed as new links to an endless chain of transformations of matter, extending from the very dawn of existence of our planet. According to the author life is no longer being evolved because with the existence of a multitude of microorganisms in every nook and cranny of the world, a new system of organic development would have insufficient time and little chance to develop in the struggle and competition for existence.

Naturally the author of such an attempt to reconstruct what happened millions of years ago, and is not receurring, may be accused of futile, long range extrapolation. However, Oparin's bold attack of the problem is truly scientific in that he utilizes only known chemical and biological processes. He eschews all romantic hunches or appeals to unknown "vital" forces. There is a "sweet reasonableness" about the whole thing.

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THE GENETICS CONGRESS

(*Continued from page* 464)

Wageningen - Amsterdam - Antwerp - Brussels-Paris-Boulogne.

Second Class	Third
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D. Hamburg-Berlin-Nurnberg-Zurich-Geneva-Paris-Boulogne.

Second Class	Third
$34.50	$23.00

Tours in Great Britain

Pre- and post-Congress bus tours in Great Britain are being arranged under the direction of Pickfords Travel Service. The pre-Congress Tour, August 15-22, will start from London (two days) thence to Cambridge (two days) and then via Ambleside, Wray Castle Fresh Water Biological Station, Kendal, Carlisle, and Moffat to Edinburgh.

After the Congress there will be a variety of tours of different lengths to the borders and Trossachs, to the north of Scotland, and to Aberdeen (Rowett Re-

(*Continued on page* 474)

A PEDIGREE OF SYNDACTYLISM

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FIVE INTO TWO

Figure 8

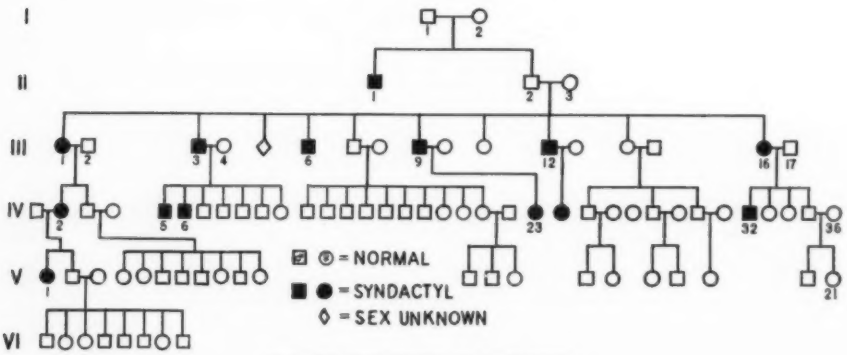
Digits of III-6 in pedigree chart (Figure 9).

HEREIN is described a family exhibiting the abnormality known under the general name, syndactylism, which may be defined as the bony fusion or fleshy webbing of digits or as the lack of certain digits. In this family the anomalies observed in the hands of different members varied from four ordinary shaped fingers, and even the possession of five-fingered hands with two digits webbed, to the extreme case shown in the photograph of the man with only two digits.

Explaining the chart: the persons denoted by III-16 and IV-23 had four-fingered hands, IV-2 had webbed digits, III-6 is shown in the illustration, and III-9 had the two typical lobster-claw extremities, that is, a hand very like the one in the picture, but actually three-fingered, two of the digits being joined or webbed. Little could be ascertained regarding the feet of any, except that club-foot occurred in II-1 and III-6; while III-9 had no feet at all, bones being altogether lacking below the knees, leaving merely elongated flippers.

Information was given me by III-6, III-9 and a third party. These were not certain of the exact forms of the defect of the other afflicted individuals.

Syndactylism is regarded as a domi-



FUSED FINGERS INHERITED

Figure 9

Six generations in the *P* Family, showing dominant inheritance.

nant character, as are also brachydactylism and polydactylism. In generation III, six or seven out of ten show the anomalies (one died at birth and the chances are it was abnormal). In the two normal of this generation that married, abnormality did not reappear in children or in grandchildren, and incidentally this must be a reassuring thought to any normal members of the family who wish to marry and who can expect to have normal offspring.

Regarding sex-linkage, this would appear probable in III-9, 10, 12, 13, and IV-23, 24, and *possible* in III-1, 2, IV-1, 2, and V-1, 2, but the cases III-3, 4 and IV-5, 6 definitely ruled out this possibility. As in any large pedigree, as that cited by Mable R. Walter,[3] cases of apparent sex-linkage will be found due merely to chance, but the whole pedigree proves autosomal inheritance.

Castle[1] however presented a pedigree of webbed toes, that it is apparently transmitted in the *Y*-chromosome from father to son, and referred to a similar character in other families transmitted from mother to daughter. "This," he says, "may possibly indicate crossing-over between *X* and *Y* chromosomes in man, as it it known to occur in Lebistes and Apocheilus (fishes), or else autosomal transmission in these other families." This is a possibility. Perhaps, too, anomalies in expression simply denote a genic unbalance (when a genic balance indicates normality) which causes some change in the embryological process. Styles and Weber[2] say however in their article on a somewhat similar digital deformity that a gene-modification is a very unlikely cause of embryological change on account of the variability in time and condition in which the different organs are established.

The actual cause of these anomalies is debatable, but there must be some inherent cell defect or failure of the gene or the organizer responsible for the development of the limbs early in embryonic life resulting in suppression or change in certain parts of the embryo.

Regarding other aspects of these anomalous individuals, their mental conditions were certainly not defective, and otherwise than their digits their physical qualities were perfectly sound.

Summary

1. Six generations of syndactyly were studied.

2. The deformity is regarded as a simple dominant variable in expression.

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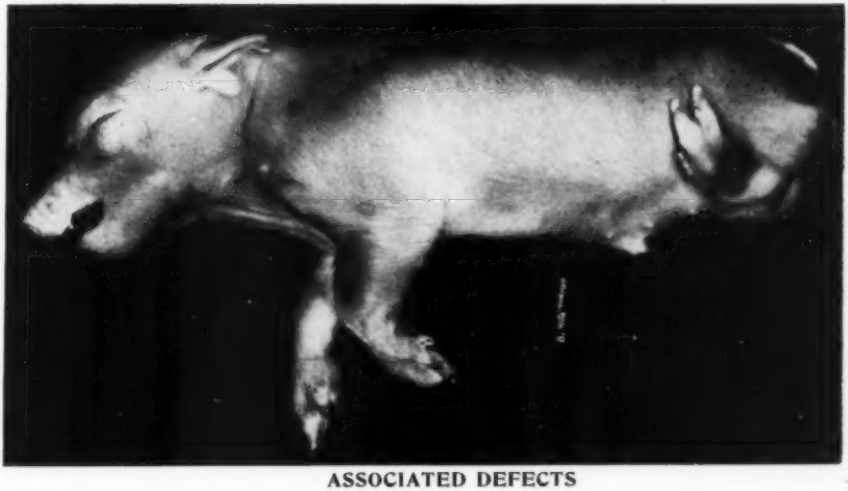
3. Walter, M. R. *Jour. of Hered.* 29:143-144. 1938.

A NEW EAR DEFECT IN PIGS

An Apparent Lethal Factor

H. E. ANNETT
Matangi, New Zealand



ASSOCIATED DEFECTS

Figure 10

View of one of the lobed-eared pigs, having defective hind quarters. Six other related pigs, with the bilobed ears but externally otherwise normal, also died at birth.

THE writer breeds Pedigree Tamworth pigs. Among his herd is a sow which has had six litters. The numbers in the successive litters were 9, 5, 11 10, 11 and 8 respectively. The first, second, third, fifth and sixth litters were all normal and all pigs in these litters, except for one born dead in the first litter, were successfully reared. The fourth litter however which was sired by a different boar from that which had sired the other litters, consisted of 10 pigs. Four of these however had ears which were split almost to the base into two lobes and of these four, three were born dead but the bodies appeared normal. The fourth pig with lobed ears was badly deformed in the hind quarters and soon died. The remaining six pigs of the litter had normal ears and did so well that at eight weeks old they averaged 54.1 lbs. Recently this matter has assumed deeper interest, since a well known pedigree in the writer's own area had 14 pigs in the litter of a certain sow. Of these 12 were normal with normal ears and the other two had lobed ears exactly like the lobed ears referred to above. These two however were badly deformed in the hind quarters. By the courtesy of Dr. Hopkirk of the Wallaceville Veterinary Research Laboratory the accompanying three photographs of one of these deformed pigs were taken by Mr. A. L. Bryant. Figure 10 shows the deformed pig complete. Figure 11 shows two views of the head, giving details of the deformed ear and of the cleft palate.

It would seem practically certain that we are here concerned with an effect which is genetic in nature. Examina-

FORKED EAR AND CLEFT PALATE

Figure 11

Two views of the head of the deformed pig, showing bilobed ear, and the cleft palate. The occurrence of pigs showing these stigma in two related herds suggests strongly that it is an inherited lethal defect.

tion of the pedigrees of the author's sow and boar and of the sow and boar of my neighbor throws some light on this matter. The boar used by me was sired by a boar which was the grandsire of my neighbor's boar. On the dam's side the author's sow was out of a sow whose full sister was the granddam of the neighbor's sow.

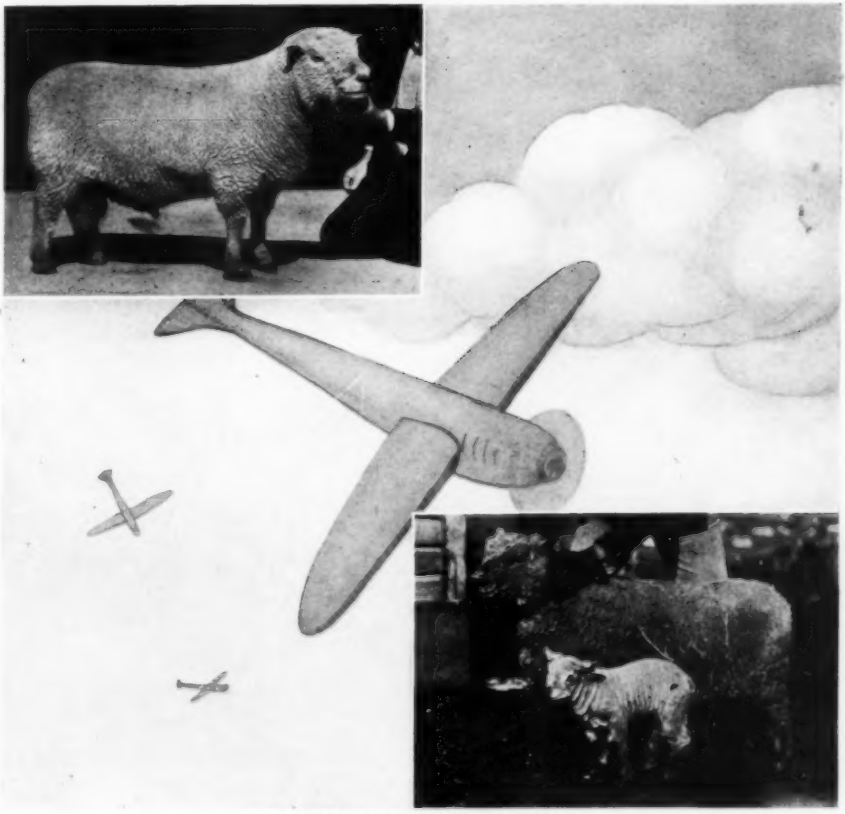
New Zealand has some excellent types of Tamworth as Dr. Hammond, F.R.S., on his recent visit to New Zealand has testified, but with the limited number of strains available there is very grave danger of inbreeding defects becoming common. The Tamworth plays a large part in pig husbandry in this country and it is therefore a matter of some urgency that New Zealand farmers will soon see their way to allowing direct imports of these and other pigs from England.

The particular type of ear defect referred to in this paper does not seem to have been described hitherto. In the "Genetics of the Pig," a reprint from the *Bibliographica Genetica*, by Buchanan Smith, Robison and Bryant, other types of ear defects are referred to. These writers state that it appears that certain types of ear defects are associated with sterility and that further, affected specimens also revealed a number of skull defects.

In the case of the defective pigs from the author's litter it is unfortunate that a cleft palate was not looked for but since in my neighbor's case the defective pigs had a cleft palate it is probable that this condition obtained in all the defective pigs.

LONGER RANGE PATERNITY IN SHEEP

RALPH W. PHILLIPS AND R. G. SCHOTT
Bureau of Animal Industry, U. S. Department of Agriculture
and
E. M. GILDOW
Idaho Agricultural Experiment Station



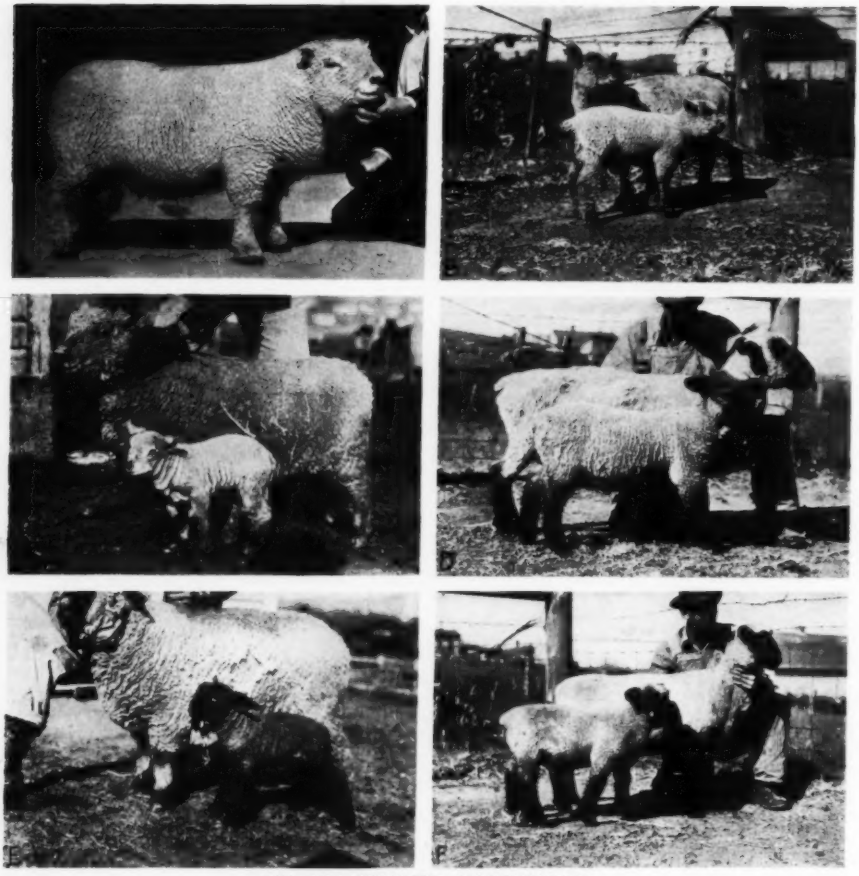
THE MAIL ORDER MALE

Figure 12

A photo-pencil-brush symbolization of successful long-range animal breeding.

SINCE Spallanzani first demonstrated the feasibility of artificial insemination about 1780 much progress has been made in developing and applying techniques for its use in livestock breeding. Limited practical use of this method of breeding has been made in this country and at the present time several State Experiment Stations and the U. S. Department of Agriculture are doing research work in this field.

Russian workers have made the most



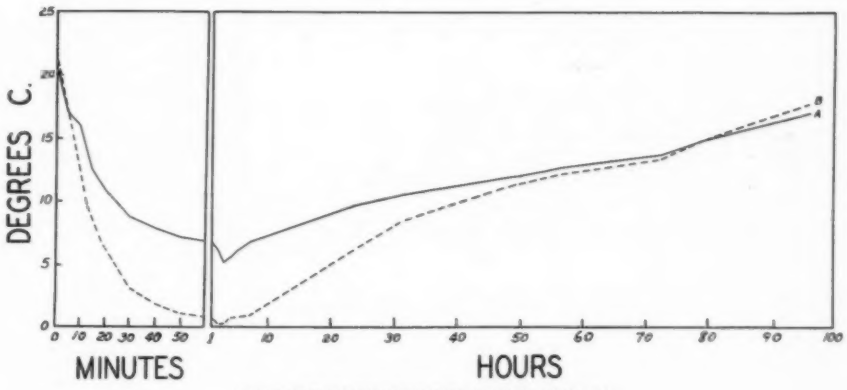
AN AIR-MINDED SHEEPFOLD

Figure 13

Lambs sired by air express, their dams and one of the rams used. *A*—Southdown ram 839, sire of lamb in *B*. *C*—Southdown lamb sired by ram 360. *D*—Hampshire lamb sired by ram 2 L. *E* and *F*—Hampshire lambs sired by ram 8 P.

extensive use of artificial insemination since it is particularly well adapted for use in the centralized breeding activities on collective farms. The extent to which it is being used is indicated by Kersin's[2] report that in 1936 8,000 insemination centers were in operation for sheep and 1,350 for cattle, in which 6,450,000 ewes and 230,000 cows were inseminated. The maximum numbers of females reported inseminated with the sperm from single sires were 15,000 ewes and 1,090 cows. In one district 45,000 ewes were reported to have been mated to 8 rams, whereas approximately 900 rams would have been required for natural mating.

Two experiments in long range paternity in sheep have been reported. Walton and Prawochenski[4] shipped semen by air mail from England to Poland. Five ewes were inseminated and two became pregnant. One of these aborted and the other produced a live lamb. Terrill and Gildow[3] shipped



THE TEMPERATURE LIMITATION

Figure 14

Showing the changes in temperature within vials packed by the method used in the shipments (*A*), and by a slightly modified method (*B*), both of which are described in the text.

semen by air and rail express from Dubois to Moscow, Idaho, a distance of about 700 miles. Sixteen ewes were inseminated at 28 different heat periods. Three ewes became pregnant and produced four lambs.

During September and October, 1937, a number of shipments of ram semen were made from the Agricultural Research Center, Beltsville, Maryland, to the Idaho Agricultural Experiment Station at Moscow. Semen was collected from four rams and seventeen samples were shipped. Some casualties occurred because of delay in transit due to bad weather and breakage in one shipment so that only twelve samples arrived in usable condition.

The semen was collected from the vaginas of ewes, either in or out of heat, immediately after breeding, placed in small vials, covered with mineral oil and corked. The small vials were wrapped with cotton and placed in larger vials which were corked, placed in vacuum bottles and packed with cracked ice and absorbent cotton. Wide mouthed vacuum bottles of one quart capacity were used. A layer of cotton was placed in the bottom, the bottle was half-filled with cracked ice, the vial was inserted and damp cotton was packed around it. The vacuum bottles were then packed in a manner suitable for express shipment, carried by auto to Washington, D. C., by air express to Spokane, Washington, and by railway express to Moscow, Idaho, a distance of approximately 2,600 miles. The time in transit varied from 29.5 hours to 74 hours and averaged 45. Upon arrival the semen was stored in a refrigerator until used.

Semen was introduced directly into the cervix of each ewe, a dosage of .2 c.c. being used. Fifty-three ewes were inseminated, seven of them at two heat periods, making a total of sixty inseminations. The time elapsing from collection to use of semen ranged from 31.5 to 200 hours. Five ewes became pregnant and produced five male lambs. The data are summarized in Table 1.

Thirty-seven inseminations were made with semen under seventy-two hours old and five lambs were produced, an average of 7.4 inseminations per pregnancy. If the seventeen inseminations with semen under forty-eight hours old are considered separately the number of inseminations required per pregnancy was 4.2.

The four rams used in this work were also used in the regular breeding activities at Beltsville during the breeding season in which shipments were made and the performances of Southdowns 839 and 360 and Hampshires 8 P and 2 L were 1.8, 2.1, 3.2 and 3.7 breedings per

pregnancy respectively, and the average figure for the four rams was 2.6. Hand breeding was practiced, and the numbers of breedings represent breedings at different heat periods. One or more actual services were allowed at each heat period, but only one breeding was charged to the ram.

The proportion of successful inseminations obtained with the artificial method is lower than that in natural breeding. This might be expected because of the age of the sperm but other factors may have had their effects. One of the mechanical difficulties in transporting semen over long distances is the cooling of the semen gradually and the maintenance of a low temperature at a uniform level. An investigation of the temperature curve in the vials packed in vacuum bottles as they were for these shipments was made. This curve is shown in Figure 14, line *A*, and it departs from the optimum in two ways. Initial cooling is too rapid and the low level of about 5° C. is not maintained. Mixing of cracked ice with the cotton packed around and over the vial resulted in some improvement in the time a low temperature was maintained (line *B*, *Figure* 14).

The problem of the rate of initial cooling can be solved by transferring the sample of semen from one container to another of successively lower temperatures before placing it in the vacuum bottle for shipment. Birillo and Puhaljskii[1] report that cooling gradually through a three hour period, with a drop of 3° every 15 minutes or 5° every 30 minutes, resulted in the least temperature shock to the spermatozoa.

Methods of packing that will maintain a low, even temperature require further investigation. If techniques entirely satisfactory for packing and shipping semen can be developed the possibilities of utilizing outstanding sires for experimental and practical breeding should be greatly increased.

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2. Kersin, I. A. Artificial Insemination of Sheep and Cattle on Collective Farms in 1936. Probl. Zivotn., No. 3, 7-10 (in Russian) 1937. Abstracted in *An. Breed. Abstracts* 5 (No. 3) 252. 1937.

3. Terrill, C. E., and E. M. Gildow. Another Experiment on Long Range Paternity in Sheep. *Jour. of Hered.* 29:77-78. 1938.

4. Walton, A., and R. Prawochenski. An Experiment in Eutelegenesis. *Jour. of Hered.* 27:341-344. 1936.

Table 1. Showing the Numbers of Inseminations Made and the Results Obtained

Ram	No. of samples	Inseminations and results: Semen used between 31.5 and 36 hours		Semen used between 33.5 and 72 hours		All inseminations		Age of semen used in successful insemination (hours)
		Insemination	Pregnancies	Insemination	Pregnancies	Insemination	Pregnancies	
Southdown 679	4	2	0	9	1	27	1	70.0
Southdown 360	1	4	1	4	1	4	1	46.5
Hampshire 8 B	5	9	2	16	0	25	2	31.5 & 46.5
Hampshire 2 L	2	2	1	6	1	8	1	70.0
Totals	12	17	4	37	3	60	5	----

The Genetics Congress

(*Continued from page* 466)

search Institute) and to other research institutes.

Prices will be quoted as soon as possible; the Messrs. Allen and Harms will represent Pickfords in arranging tours for American members of the Congress.

Group Sailings

If a number of members of the Genetics Society of American plan to sail together, there may well be distinct advantages in accommodations and costs. For these advantages, the party need not return as a group. The most practical possibilities are:

A. Anchor line *California* August 2, New York-Boston to Glasgow.

B. Canadian Pacific *Empress of Australia* August 3, Quebec to Southampton.

C. Cunard White Star Line *Britannic* August 5, New York to Southampton and London.

It will be necessary for the secretary to know well in advance how many members care to participate in a group sailing. Those who contemplate attending the Edinburgh Congress are urged to get in touch with Dr. Lindstrom, or with the Allen-Harms Travel Agency (509 Welch Ave., Ames, Ia.) as soon as possible.

SEED BEDS OF AMERICA

A Review of "Problems of a Changing Population"

J. J. Spengler
Duke University, Durham, N. C.

RECENT years have witnessed, in many countries, an intensification of interest in demographic trends and their implications. Inquiries into the determinants of these trends are multiplying, and legislative measures designed to redirect these trends are being proposed, and at times being put into effect. Unfortunately, however, presumably because of the resurgence of tribal nationalism, and because of the growing fear of national depopulation, the bulk of present-day interest in demographic trends is centered upon *quantitative* rather than upon *qualitative* aspects of population growth.

With the establishment of the National Resources Board in 1933, and with its recognition in 1934 that "human resources and human values are more significant than the land, water, and minerals on which men are dependent," governmental cognizance of American demographic trends was taken. *The Problems of a Changing Population** (hereafter called *Report*), prepared by a technical staff under the direction of Dr. Frank Lorimer, secretary of the Population Association of America, constitutes the first governmentally financed contribution (since the period of controversy over national immigration policy) to the establishment of a factual groundwork on the basis of which a national demographic policy may be formulated.

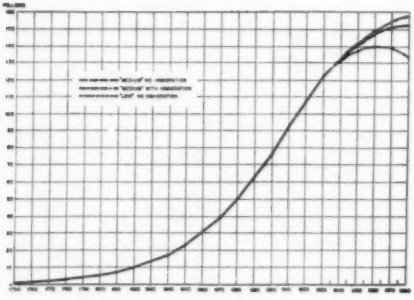
With one qualification† this study, with its many maps, tables, and bibliography, is the most comprehensive available summary of both published and unpublished materials pertaining to American demographic and cognate problems. Separate sections of the study are devoted to trends in general population growth, to changes in the composition of the American population, to past and probable trends in the geographical distribution of the population, to the present regional distribution of economic opportunity, to the extent and causes of differential fertility and natural increase, to the physical characteristics and biological inheritance of the present population, to health and physical development, to social development and education, and to cultural variations and trends in American life.

Adverse Selection in America

Of the various findings of the scholars who prepared this *Report* none will interest the readers of this JOURNAL more

*United States Government Printing Office, Washington: 1938, Pp. iv, 306, 75c. See also National Resources Committee reports on *Our Cities* and on *Population Statistics* (Parts I-III); the report of the President's *Advisory Committee on Education* (1938); H. Odum, *Southern Regions;* J. J. Spengler, "Population Problems in the South," *Southern Economic Journal,* April, July, and October, 1937; *Research Bulletin* of the N.E.A., XV, 1937, Nos. 1, 3-4.

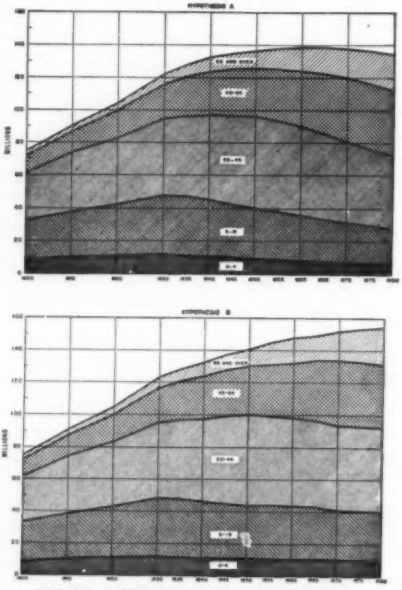
†The section of this monograph, prepared by Dr. C. V. Kiser and dealing with "factors underlying group differences in fertility," was cut and published in the first printing in a conclusion-distorting form without the knowledge of Dr. Kiser or the technical director. Dr. Kiser had shown in his original study, and without expression of approval or disapproval, "that group differences in fertility rise largely through differences in the acceptance and practice of contraception." In the report, as first published, this finding and the data supporting it are not presented. See *The New Republic,* August 17, 1938, pp. 30-31; F. Notestein, *Population Index,* July, 1938, p. 136. In a second printing of the *Report,* soon to be released, we are informed that this unfortunate situation has been remedied by the inclusion of a brief but comprehensive statement by Dr. Kiser of his findings and conclusions with regard to this important matter. It is a pleasure to be able to report that so unfortunate a blemish to a fine pioneering survey is being removed.



THE CURVE OF POPULATION GROWTH

Figure 15

Actual growth from 1750 to 1935, and estimated growth to 1980 on three assumptions made by the experts of the Scripps Foundation. "Medium" and "low" refer to fertility, both have been combined with "medium" mortality. The charts reproduced with this article represent only a small sample of the one hundred and fifty charts which illustrate the report. Those copies here have been considerably reduced on account of limited space, but give an idea of the excellence of this material.



HOW AGE-GROUPS MAY BE DISTRIBUTED

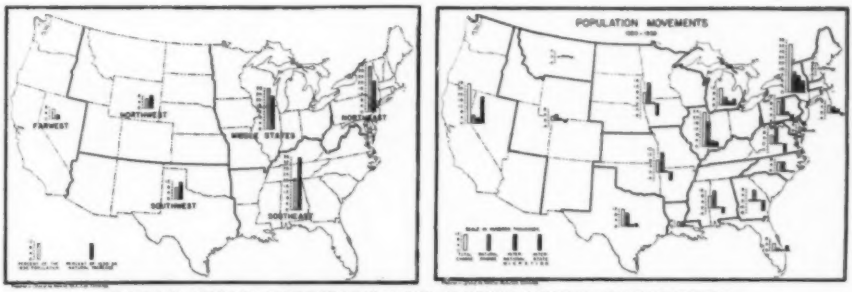
Figure 16

In hypothesis *A*, medium mortality, low fertility, and low immigration are assumed, between 1935 and 1980. In hypothesis *B*, medium mortality, medium fertility, and low immigration are assumed during the same period.

than the evidence that today demographic selection is sociologically and apparently biologically dysgenic. The data clearly indicate that an abnormally large proportion of tomorrow's population is being supplied by families socio-economically unequipped to maximize the biological potentialities of their offspring, and in geographical regions comparatively deficient in socio-economic resources and opportunities. The data inferentially indicate that a disproportionately small fraction of tomorrow's population is being supplied by families possessed of the characteristics usually associated with superior biological endowment. These two findings will be treated in reverse order.

That reproductive selection in the United States is biologically dysgenic is not inferrable directly from the available statistical data; it must be deduced indirectly from materials pertaining to differential fertility. The bulk of the data pertaining to family size and intelligence ratings do indicate that "children making high scores in intelligence tests come on the average from smaller families than do children with low ratings (p. 147)." However, even granting that *"within* groups that are similar with regard to geographical location and social status hereditary factors apparently outweigh the environmental in determining differences in individual ability (pp. 161-62)," and that more of the variance of I.Q. is attributable to heredity than to environment (p. 162), the evidence here presented on the relationship betwen family size and "intelligence" (as defined by the operations making up "intelligence" tests) is too limited in quantity and representability, and too non-uniform in character, to permit the conclusion that reproductive selection in the United States is biologically dysgenic.

For the preceding and other reasons no unconditional answer is supplied to the question: Is migration intensifying



POPULATION INCREASE AND POPULATION MOVEMENT

Figure 17

Percentage of total population and total natural increase 1930-34 by six principal regions is shown on the left. Total population movements by smaller groups of states are shown on the right. In this period interstate migration has been away from the South and Mid-west toward the far West and the Northeast.

dysgenic selection by carrying the more able from milieus relatively favorable to fertility to milieus relatively unfavorable to fertility?

There is little or no valid evidence proving that rural-urban migration is depleting the biological stock of the country. Various studies demonstrate that those who leave have attended school more years than those who remain. Migration of the better trained undoubtedly has social effects which are probably much more important at present than deterioration of biological stock. There is the further consideration that unless the prospects of farm living are attractive, increase in communication and in freedom of movement may make rural-urban migration far more selective in character in the future than it has been in the past. If this is true, it points clearly to a need for improving both the economic and the social conditions of rural life, especially of farm life in areas where the outlook is now discouraging. (p. 112)

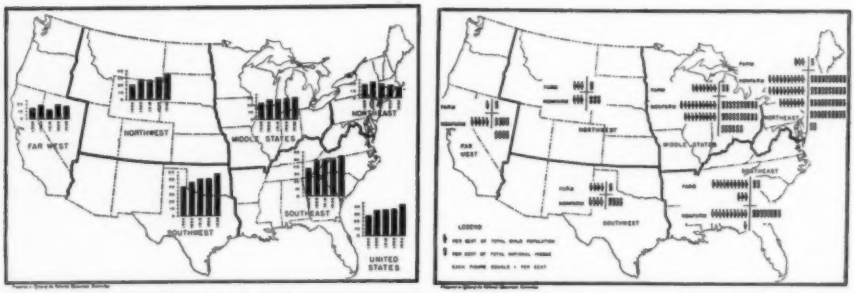
Even though it is impossible to infer directly from the available statistical materials that reproductive selection is biologically dysgenic, this conclusion may be elicited indirectly. It requires to be shown: (a) that socio-economic selection has been and still is competitive in nature; (b) that in such competitive selection superior biological endowment constitutes a differential advantage for competitors so endowed; (c) that the rate of natural increase is lower in elevated than in depressed socio-economic strata.

Scattered studies of socio-economic selection — i.e., of vertical mobility, — together with what may be expected on *a priori* grounds, support the conclusion that socio-economic selection has been quite competitive, and that as a consequence the more talented have tended to rise in socio-economic rank in a relatively more marked degree than the less talented. For as Hankins* observes:

The acceleration of the upward movement of able individuals has been greatly stimulated by three social conditions. The phase of cultural evolution through which we have been passing, with its unparalleled material advancement, has called for all the latent talent the population could supply. There has not been lacking abundant opportunity for able and energetic men and women to elevate themselves in social scale. Then, as already noted, we have provided an elaborate educational machine to facilitate the discovery and training of able individuals. This machine has acted like a gigantic sorting apparatus, dropping out the less gifted at an early stage and carrying along the more gifted to higher levels. In the third place, the failure of the upper classes to add their full quota to succeeding generations has served to create vacancies to be filled by mobility from lower levels.

That there are "marked differences between occupational groups in their cultural-intellectual development as mea-

**Social Forces*, XII (1933), pp. 38-39; also N. J. LENNES, *Whither Democracy*, New York, 1927.



FARM TENANCY AND DISTRIBUTION OF CHILDREN AND OF WEALTH

Figure 18

On the left is shown the percentage of farms operated by tenants, 1880-1930; and on the right the distribution of farm and non-farm children and national income in 1930 for six regions of the United States. It is clear from this map that there are tremendous differences in the ratio of income to children in various parts of the United States.

sured by intelligence tests" is shown by almost all of a large number of American studies of the relationships between occupations and "intelligence." When income and other indices of social status are employed, somewhat similar results are obtained. "One of the most striking results" of the survey by Lorimer and Osborn* is "the relatively high frequency of persons of unusual ability in the upper social groups and the relatively high proportion of mental defectives or persons with very inferior intellectual development in the lowest social groups." That this distribution of ability by socio-economic class reflects somewhat a corresponding distribution of an hereditarily transmitted "mother wit," or "natural capacity to understand complexities and grasp ideas," is suggested by the findings of English psychologists with respect to the general mental capacity which they label the "G" factor.†

In view of what has been said, the following significant findings of the *Report* (chap. v) are quoted or summarized:

1. "Recipients of relief are more fertile than the general population."

2. "That fertility rates are generally higher in the underprivileged groups than in the higher income groups has been found consistently, regardless of whether the index of economic status is income, rents paid by single families, or average rentals in given areas."

3. Birth rates in the so-called upper occupational groups are lower than those among the laboring classes. . . . Urban fertility rises with "lowering" occupational status. . . . Within certain limits, at least, there appears to be a persistence of occupational differences in fertility when incomes are virtually the same.

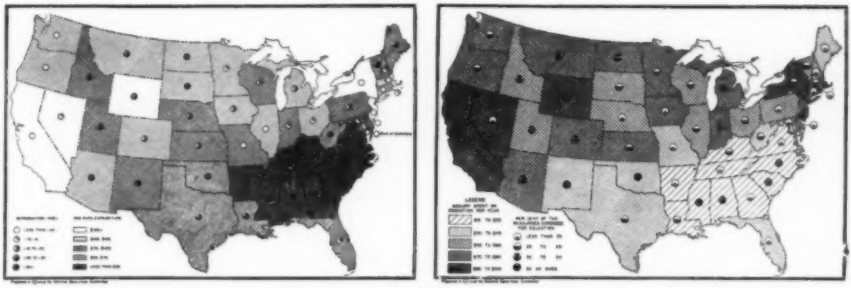
4. Although fertility by occupation has varied inversely with size of community in the past, the relative differences between occupational classes remained fairly constant.

5. Married couples with little or no schooling have more children, on the average, than those with a moderate or a considerable amount of education. On the other hand, the inverse association between education and fertility is not a rigid one. There are indications that, after certain levels of education are attained [probably high school education, inasmuch as there is little difference, *caeteris paribus*, between the fertility of those with high school education and the fertility of those with college education], further schooling has little effect upon fertility when other factors are held constant.

6. Variations in mortality by occupation do not counterbalance analogous variations in fertility. The total farm population supplies about 60 per cent more births than are required for replacement, fertility and net replacement within the farm population varying inversely to occupational and income status. While the total nonfarm population just about replaces itself, the professional and business classes fail by 25-15 per cent to replace themselves, actual replacement in the non-farm population being

**Dynamics of Population*, New York, 1934, chap. viii, especially p. 176.

†CATTELL, R. B. *The Fight For Our National Intelligence*, London, 1937, chap. iii; also R. KNIGHT, *Intelligence and Intelligence Tests*, London, 1933.



THE EDUCATIONAL DOLLAR AND THE REPRODUCTION INDEX

Figure 19

On the left is shown the annual cost of education per pupil (shaded areas) in relation to reproduction index (segmented circles) by states. Where the reproduction index is high (black circles) the expenditure per pupil is low (heavy shading). The reverse of this is also true: New York and California with the lowest reproduction indices have the highest expenditures per pupil. On the right are shown the expenditures per pupil per year (shaded areas) and the per cent of tax resources expended for education (segmented circles) in 1930. (Estimates by Chism.)

attributable primarily to the exces fertility of skilled and unskilled labor.

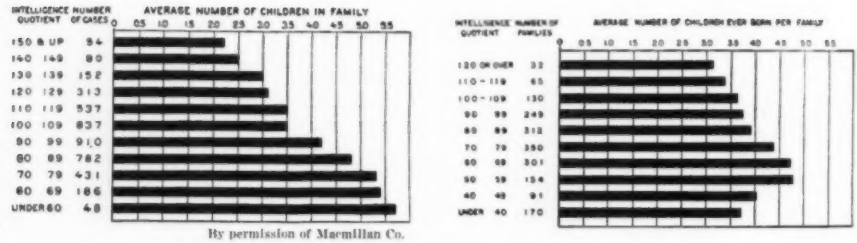
Whatever be the implications of racial and nationality differences in fertility in the United States* and whatever be the causes of the socio-economic class differentials in fertility and natural increase summarized above,† these differentials clearly indicate that reproductive selection in the United States is dysgenic *if* the argument advanced above is valid. For these differentials indicate an infra-average rate of natural increase in the very classes of the population which, in light of the preceding argument, are relatively loaded with persons of superior biological endowment; and a supra-average rate of natural increase in the classes that are comparatively deficient in persons of superior biological endowment.

Although the present study supplies estimates of the number of temporarily and permanently sub-marginal persons in the American population,‡ no estimate of the rate of dysgenesis is provided. Lorimer and Osborn (*op. cit.*, pp. 188-93), however, have estimated that, given present differential reproduction, the median I.Q. is declining nearly one point per generation (the decline in the

*In recent years the fertility of foreign-born white women has decreased much more rapidly than that of native white women, or that of Negro women. At present the birth rate of foreign-born white women is only 10-15 per cent higher than that of native white women. Although the birth rate of Negro women approximates that of foreign-born white women, higher mortality among Negroes reduces their rate of natural increase to parity with that of the white population. Among the Mexicans gross and net production are much higher than among whites or Negroes. See chap. iv, especially pp. 127-29.

†Variations in the degree of acceptance and practice of contraception appear to constitute the principal immediate cause of these class differentials in fertility. Variations in natural fecundity, traceable to the biological consequences of economic and marital selection, probably account for only a minor fraction of these differentials. As late as 1910 rural-urban and occupational differences in fertility were "due not so much to variations in proportions of childlessness as to differences in proportions of large families." In the past and to some extent at present deferment of marriage has depressed somewhat the fertility of both urban "white-collar" workers and college women. See chap. v; also note 2 above.

‡The number of persons suffering from mental deficiency, a condition attributable primarily to hereditary factors, is estimated at 1,500,000; the number suffering from mental diseases, a condition attributable only in part to hereditary factors, is estimated at 1½ to 2 millions. The blind number slightly over 100,000; the deaf mutes, at least 59,000. Cripples number about 700,000. Sickness disables, on an average, about two per cent of the population, thus reducing national productivity perhaps as much as 4 billion dollars. See chaps. vi-vii.



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I.Q.'S AND THE DIFFERENTIAL BIRTH RATE

Figure 20

Distribution of families by size in relation to intelligence quotients of children, based on data collected from 4,333 cases by Lentz (left) and on 1,854 cases collected by the Institute of Juvenile Research, Chicago (on right). There is a striking parallelism between the two groups, with the Chicago families averaging larger in the upper brackets and somewhat smaller in the lower brackets than Lentz's families. Lentz's graph is from Lorimer and Osborn. *Dynamics of Population;* the Chicago data are from Thurston and Jenkins, *Order of Birth, Parent Age and Intelligence.*

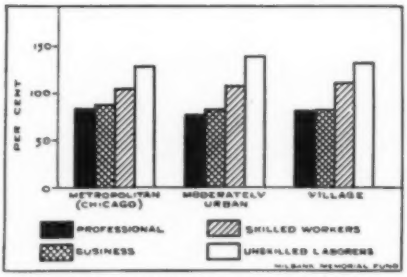
mean is slightly larger). The relative number of persons with an I.Q. of 120 and over declines about 10.6 per cent per generation; the relative number with an I.Q. under 80 increases about 5.8 per cent per generation (see Table I). In Table II are given somewhat comparable but much more carefully obtained data for England, based upon representative surveys of urban and rural populations, under the direction of Dr. R. B. Cattell.* In urban England the average I.Q. is now falling about three points per generation. The relative number with an I.Q. of 140 or more is declining 17.6 per cent per generation; that with an I.Q. of 120-140 is declining 17.4 per cent; that with an I.Q. under 80 is increasing 23.5 per cent.

Socio-economic Dysgenic Selection in America

As certain of the data already presented indicate, a large proportion of the citizenry of tomorrow is being procreated and reared by underprivileged parents and in underprivileged regions; for, as the figures in Table III show, economic opportunity is unevenly distributed, and children are relatively most numerous precisely in those regions where opportunity is most lacking. At present about 55 per cent of the nation's natural increase comes from three regions — Southeast, Southwest, and Northwest — that contain about one-third of the nation's population and receive only one-fifth of the nation's income.

State data corroborate the regional figures. The 24 states which in 1930 ranked highest in net native white reproduction included 19 of the 24 states ranking lowest in per capita income; the 16 states ranking highest in per capita income included 10 of the 12 wherein fertility had fallen below the replacement

*Table II is adapted from Cattell (*op. cit.*, pp. 12-13, 42-44). "By a convention arising from experience the mental defective is a person having an I.Q. below 70. A child in school who is considered dull and backward is commonly found to have an I.Q. below 80. Scholarship children (for secondary schools) are almost invariably above 120, whilst a strikingly brilliant child has an I.Q. of 150-170." See *ibid.*, p. 23. Elsewhere Cattell says: "For purposes of discussion I shall divide the distribution of intelligence into five parts. At the lowest extremity the *feebleminded*, below an I.Q. of about 70 and constituting perhaps as much as 3-4 per cent of the population; next the *sub-cultural* below an I.Q. of 85 constituting about 20 per cent of the population; then the middle, average group consisting of 50 per cent of the population and ranging in I.Q. from 85 to 115. This we may call the *foundation* or *average type* of the population, and above it lies 20 per cent of *able* people (the average secondary type) ranging from 115 to 135 I.Q. At the top we have at present 5 per cent of *highly gifted*, mainly between 135 and 180 I.Q." A *sub-cultural* defective is one unable to fulfill the economic and political obligations incumbent upon a citizen of a democratic commonwealth. See *ibid.*, pp. 106-09.



THE URBAN-RURAL AND OCCUPATIONAL DIFFERENTIATION

Figure 21

The standardized birth rate for native white wives under forty-five years of age in each occupational class is shown as a percentage of all classes combined in the same community. There is a close parallelism between the groups in metropolitan, urban and village communities. From Kiser, *Jol. Amer. Statis. Assoc.*, 1932.

level. The 20 states ranking lowest in per capita income contain 36 per cent of the nation's population and 40 per cent of the nation's children of school age, but receive only about 18 per cent of the nation's income; these states could provide, even under a standard tax plan, only one-fifth of the national revenue obtainable for primary and secondary schools. The ten least prosperous states —all Southern—contain 19.7 per cent of the nation's population and 23.2 per cent of the nation's children of school age, yet receive but one-eleventh of the nation's income. Were the Southern states to support education at the same level of expenditure as the entire nation, Southern educational expenditures would consume almost all the tax revenue actually raised, and three-fifths of all revenue obtainable through a model tax system. Within the 13 states (all of which lie in the South and Southeast) ranking lowest in terms of the most comprehensive cultural indices live nearly one-third of the nation's children under 15.

County data tell the same story. The 356 counties (i.e., about one-ninth of all counties) wherein fertility is at or below the replacement level and where live more than one-half of the population, generally rank among the most prosperous of American counties. The 113 counties wherein population is doubling each generation lie in the Southeast and Northwest and are generally relatively unprosperous. In the poorest counties in America fertility is 77 per cent above the replacement level; in those with the highest level of living, 17 per cent below. Fertility is about twice as high in the lowest as in the highest of the six groups

TABLE I*

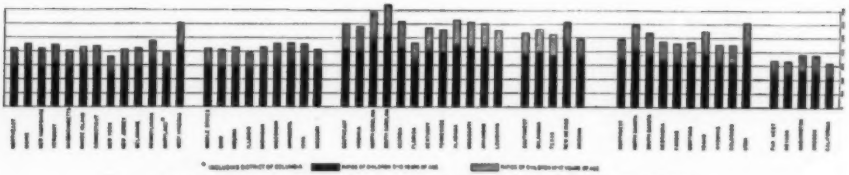
Haggerty I.Q. Classes	First Generation Per Cent of Total	Second Generation Per Cent of Total	Change Per Cent
140 and over	1.71	1.50	—12.3
120-140	10.42	9.34	—10.4
80-120	69.10	69.32	+00.3
Under 80	18.77	19.85	+ 5.8
Median	I.Q. points 95.90	I.Q. points 95.01	I.Q. points — 0.89

*Adapted with slight change from Lorimer and Osburn, *op. cit.*, p. 190.

TABLE II*

Population Class	Percentage of population in given generation with given I.Q.												Average I.Q., by generation		
	Below 80			80-120			120-140			140 and over					
	L	P	F	L	P	F	L	P	F	L	P	F	L	P	F
Rural	17.24	20.67	24.02	69.51	70.35	69.76	7.43	5.49	3.95	5.81	3.61	2.20	96.7	93.4	90.6
Urban	11.04	13.78	17.02	69 40	69.99	69.59	12.12	10.15	8.38	7.38	6.03	4.97	103.9	100.8	98.1

* L = Last generation; P = present generation; F = future generation.



THE CHILD-ADULT RATIO-CALL OF THE STATES

Figure 22

Number of children 5-13 years and 14-17 years to one thousand adults age 20-64 by region and state 1930. Great regional differences in reproductive activity are emphasized by this chart.

of American counties classified according to plane of living. Within the three lowest of these six groups, the bulk of which lie in the Southeast and Southwest, live nearly three-eighths of the nation's children under five and slightly over one-fourth of the nation's women of child-bearing age.

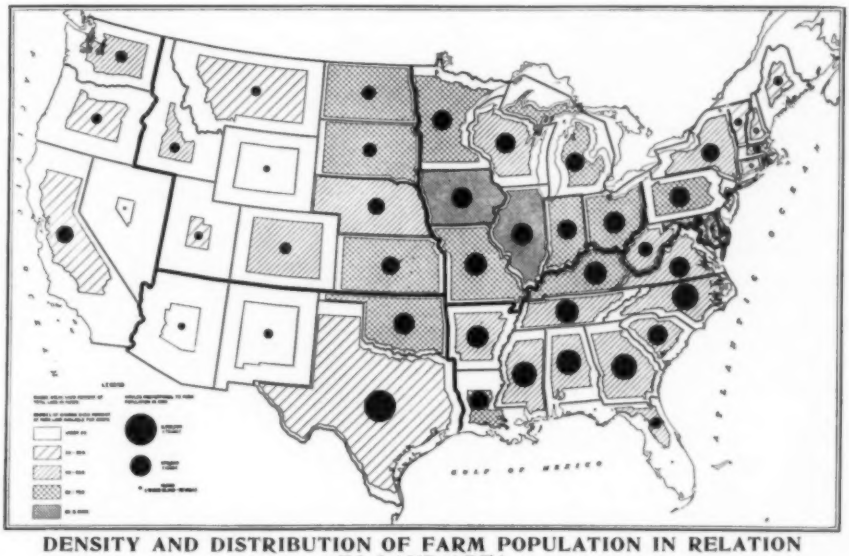
Much of the discrepancy noted between abundance of economic opportunity and abundance of offspring is attributable immediately to the fact that the non-wealthy but fecund rural population is very unevenly distributed throughout the United States. Already in the late 1920's the urban native white population was dying out at a rate of 14 per cent per generation, only populations in cities under 10,000 producing enough children to replace themselves; the urban Negro population was dying out at a rate of 29 per cent per generation. While the cities devoured population, rural areas produced enough births to swell the population of the entire nation about 10 per cent per generation, the rural native white population multiplying 54 per cent per generation and the rural Negro 58 per cent per generation. Native whites on farms multiplied 69 per cent per generation; Negroes on farms, 78; rural village whites, 37; rural village Negroes, 21. Within rural problem areas (i.e., areas in which a considerable part of the crop land is slated to be transferred to non-crop uses) net reproduction (= 1.80) is appreciably higher than in rural non-problem areas (= 1.60), the fertility of women in the problem areas exceeding that of women in non-problem areas by about 10 per cent.

The fertile rural-farm population, comprising one-fourth of the nation's people and 30 per cent of the nation's children under 15, receives only one-eleventh of the nation's income. In 1935-36 in rural village and open country schools expenditure per pupil in attendance was but five-eighths of that in urban schools. In the open country schools attended by more than one-half the rural children, the expenditure level was even lower, especially in the South where the farm population, with 13.3 per cent of the nation's children, received only 2.2 per cent of the nation's income. Low rural income and school expenditure levels assume concrete form in a predominance

TABLE III*

Region	Income in 1929		Children, 5-17	
	Per-Capita (dollars)	Per Cent of National Total	Per Cent of National Total	Per 1,000 persons, aged 20-64
Far West	921	8.87	5.48	336
Northeast	881	42.93	29.66	420
Middle States	715	28.38	26.06	423
Northwest	590	4.59	6.26	496
Southwest	564	5.22	8.13	537
Southeast	365	10.01	24.41	603

* Data from *Problems of a Changing Population*, pp. 43, 201, 207.



DENSITY AND DISTRIBUTION OF FARM POPULATION IN RELATION TO LAND AREA

Figure 23

The dark circles show proportional total population in 1930. The shaded outlines show per cent of total land in farms. Degree of shading shows per cent of farm land available for crops. This map attempts to show the "true density" of farm population, in the light of the available land area. Some of our "sparsely settled" states appear fully as heavily peopled as more populous regions when their true "arable size" is mapped.

of one-room schools, in deficient teaching, equipment, and service, and in the non-attendance (in 1930) of nearly 800,000 rural children.

Although the data are not available in forms that permit ready summarization in national terms, it appears likely that the 60 per cent of the nation's families who receive but one-fourth of the nation's income are contributing at least 75-80 per cent of the nation's growth. Wherefore it is evident that, whatever be the biological implications of these figures, the bulk of the nation's children are growing up in culturally poverty-ridden milieus unsuited to develop fully the new generation's biological potentials (other than capacity to procreate); for various socio-economic lackings (e.g., educational, library, public and private health, communal welfare) are generally associated with income lackings.

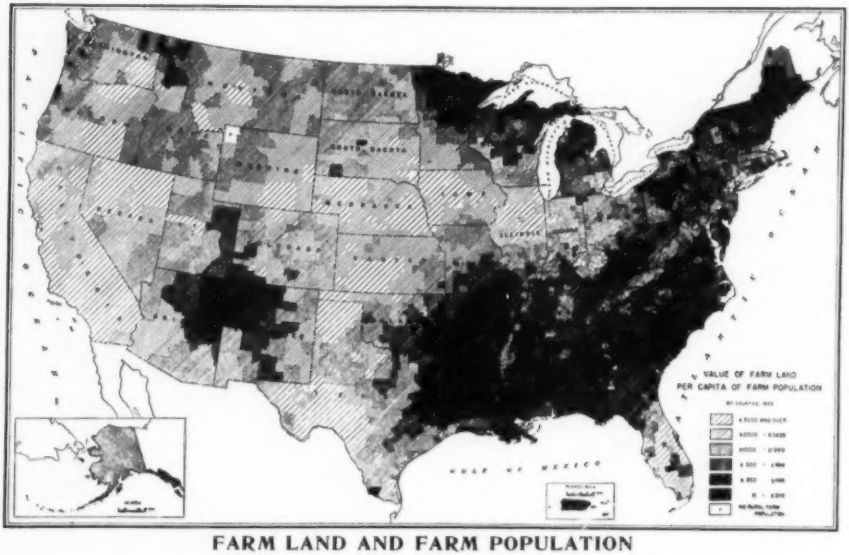
Every type of analysis . . . has indicated wide geographical variations in the relation between population and developed resources. . . . Facts further emphasize the necessity of a large continuous migration from the less productive agricultural areas, unless the level of living — already far too low — is to be depressed still further. They suggest that, in the long run, changes in fertility may have a profound effect on the distribution and characteristics of the people of the United States. (Pp. 82, 138)

* * *

The data presented . . . lead inevitably to the conclusion that that part of the Nation most able to support a large number of children has relatively few. On the other hand the poorer rural areas, with low incomes and levels of living, and consequently with least ability to carry the burden of a large child population, are producing a disproportionate part of future generations. The continuation of present differentials in fertility will increase rather than decrease these economic inequalities. (P. 139)

Implications for the Future of America

It hardly requires the ill-auguring eye of a Cassandra to foresee that present



FARM LAND AND FARM POPULATION

Figure 24

The value of farm land per capita of farm population is high in the light areas of the map, and low in the dark areas. From another angle this map tells the same story that is told in Figures 18 and 19,—that the relation of population to resources shows many disparities.

selective trends do not omen well for the future.

We may conclude that an informed appreciation of the nature of complexities of biological inheritance and of the operation of social inheritance tends to focus attention on variations in reproduction rates among large population groups and among individuals distinguished with respect to health, character, and present intellectual attainments. The best guarantee of sound biological and social national development would appear to be a situation in which the determining factors in size of family would not be ignorance, isolation, or indifference as contrasted with ambition and anxiety, but interest in child life and ability to provide favorable environment for child development. (P. 165)

Precisely what present selective trends augur for the future must be inferred, for our knowledge of the causes and effects of "intelligence" is limited. Moreover, dysgenic differential selection is a comparatively recent phenomenon, judging from English data; and its effects, to date, if any, have been masked by cultural progress. However, even though past history cannot be extrapolated into the future, inference suggests at least seven implications of present biological trends.

1. *Biological decay may check and even reverse the seemingly inherent tendency of culture and knowledge to cumulate in the community and improve man's physical and spiritual lot. For since many tasks, occupational duties, and social obligations can be fulfilled only by persons with at least minimum I.Q.'s, a continual decline in the relative number of persons with I.Q.'s of 120 or better (such as the data in Tables I and II suggest) will inevitably result in an insufficiency of persons to perform tasks requiring a high I.Q.* and in a deficiency of the inven-*

*That intelligence is of more importance in modern technological than in earlier economies seems to be evident from: (a) the increase in the relative number of occupied persons who are engaged in the more intelligence-requiring occupations; (b) the much heavier incidence of unemployment upon the less skilled and less intelligent than upon the more skilled and more intelligent. See A. H. Hansen, *Full Recovery or Stagnation?*, New York, 1938, pp. 305-06.

*tive minds whereon the augmentation of per capita wealth chiefly depends.**

2. *The average cost per child of imparting a given amount of education will be increased considerably, and the content of that education will be reduced; for inferior intelligences are slower to learn that which they can learn.*
3. *The fabric of folkway, mores, and custom, hitherto somewhat dynamic and somewhat marked by a tendency to greater complexity and variability, will tend to become simplified and to crustify; for dynamism is positively correlated with intelligence.*
4. *Criminality and discontent will tend to increase, other things equal; for inferior intelligences find it harder to win happiness in competition, or to discover it within.*
5. Panem et circenses *will tend to be accorded increasing weight in the nation's recreational and cultural diet; for inferior intelligences require such to be amused.*
6. *Both the moral and the military capacities of the population will deteriorate; for those capacities require intelligence minima.*
7. *The philosophical and cultural foundations of democracy will tend to dissolve as a paucity of intelligence-equipped leaders develops.*†

Of greater immediate import than present biological selective trends is the fact that so large a proportion of the population is growing up in culturally deficient milieus. For these milieus alter the structure of what may be called the nation's value scales, and thus tend both to aggravate present dysgenic biological trends and to destroy the very politico-cultural bases of modern civilization.

> The environment of one generation can produce a lasting result, because it can affect the environment of future generations. *Environments, in short, as well as people, have children.* Though education and so forth cannot influence new births in the physical world, they can influence them in the world of ideas; and ideas, once produced or once accepted by a particular generation, . . . may not only remodel from its very base the environment which succeeding generations enjoy, but may also pave the way for further advance [or retreat]. . . . A permanent . . . change of environment . . . may produce enduring consequences.‡

The value scheme prerequisite to the reversion of present dysgenic biological and social trends cannot prevail, let alone flourish, so long as a preponderant majority of the population not only is reared and conditioned in pronouncedly deficient cultural milieus, but also is empowered through the right of suffrage to veto the forces of progress. This need for high cultural standards in a Democracy was recognized by the founders of this country and has never been seriously questioned. Only certain types and levels of education are suited, on the one hand, to preserve democracy, on the other to inculcate a value scheme appropriate to eugenic selection, to inspire respect for such a scheme, and to implement the will to effectuate such a scheme. Under present circumstances such a value scheme appears as unlikely of inculcation as that spirit of cooperation — a spirit itself presupposing intelligence and

TABLE A

I.Q. Classes	Actual	Three generations hence	Required Minimum	Hypothetical Desideratum
140 and over	6.0	3.3	4	10
120-140	10.0	5.5	8	15
80-120	70.0	66.5	70	70
Below 80	14.0	24.7	18	5

*Let us suppose that the population is distributed by I.Q. as in column 2 of Table A; that three generations hence the distribution becomes, in consequence of dysgenic selection, as in column 3; that the minimum distribution required for the preservation of modern culture is, as in column 4; that an hypothetical ideal would approximate the distribution in column 5. Then within a century biological decay would have *reversed* the progressive tendencies in man's cultural equipment.

†Cattel (*op. cit.*, chapter iv) develops some of these points at length.

‡Pigou, A. C. *Economics of Welfare*, 4th ed., London, 1932, pp. 113-14. Reviewer's italics.

understanding — whereon, as S. Casson shows (in *Progress and Catastrophe*), depends the very preservation of modern liberal culture.

Intensification of relative cultural retardation in populations and groups living in very depressed circumstances endangers a national political and economic structure in various ways. Migrants from depressed areas prove difficult of assimilation in advanced areas. More important: as the relatively uneducated underprivileged become aware of their economic lackings, they will increasingly seek to redress their economic grievances through political means that in the longer run may be inimical to their own welfare and to that of the community; they will increasingly support rabble-rousers who do not understand or refuse to understand the basic causes of underprivilegedness, and who instead advocate anti-chain store laws, "home market" legislation, "thirty dollars every Thursday," "pie in the sky," laws designed to hobble interstate commerce, and measures calculated to aggrevate already existing monopolization and to palsy such production- and income-expanding tendencies as still prevail in the American economy. Measures of this sort aggravate the very evils they are supposed to remedy and gradually give rise to situations favorable to violent revolution, mass support for which comes from the inner barbarians now being created, barbarians who seemingly have little to lose and much to gain. In Mr. Ickes' words: "The insecurity of great masses of the people breeds desperate hopes and desperate measures." When insecurity and ignorance exist side by side the lamps of reason go out; and when the lamps of reason go out, rational values, whether eugenic or not, decay.

Is There A Way Out?

Is there a way out? The question is neither posed in its full meaningfulness by the authors of the *Report* nor answered. Although the authors rightly emphasize the need for more factual data, one feels that their emphasis upon this need is but the hand of the Esau of research; that their request for more facts is essentially the voice of a timid Jacob unwilling to make full inference from the available facts. Only the author of the chapter on health admits that enough is known to "afford a sufficient basis for trial and experiment" in solving the problem of the organization of medical care, and realizes that only out of such trial and experiment can effective solutions come. In my opinion the real need at present is not so much more data as the devising of means whereby existing data may be used as a foundation for action. Scientists need the arts of the demagogue and public relations counsel to make the Nation aware of the demographic facts and their implications, and of the necessity for action. Otherwise the lamps of reason may go out while researchers seek "further facts," but facts for which there is no immediate and pressing need.

The need for the greater equalization of educational opportunity as part of the way out is clearly recognized in the *Report*.

> The inequailties of educational opportunity that exist between rural and urban communities constitute a challenge to our ideal of democracy. Education can be made a force to equalize the condition of men; it is no less true that it can be made to create class, race, and sectional distinctions. The evidence indicates clearly that continuance of present practices creates grave danger that our schools which we have heretofore regarded as the bulwark of democracy, may in fact become an instrument for creating those very inequalities they were designed to prevent. . . . There may be reasons why the Federal Government should not participate in the support of education in the States, but these reasons should be weighed against the certainty that if the States are left to their own resources the existing inequalities of educational opportunity will be perpetuated for a generation, if not indefinitely. (P. 221)

It is indicated roughly where economic opportunity is relatively greatest.

> Manufacturing and mechanical industries are concentrated chiefly in the Northeast and Middle States. Analysis of recent trends indicates some movement away from the old manufacturing centers, but the main trend seems to be toward a persistence of the general pattern of concentration and dispersion as found at present, with slow diffusion of industry within the principal industrial areas and the occasional emergence of new industrial centers, rather than toward any general dispersion of indus-

try. . . . The opportunity for employment in the more desirable and more remunerative occupations is greatest in the Northeast and the Far West, and most restricted in the Southeast. (P. 82)

It is recognized that neither the relocation of the population, nor the improvement of the milieus of the underprivileged, is likely to proceed rapidly in the absence of collective action.

A variety of conditions, some of which are subject to social control, tend to impede the adjustment of population to economic opportunity through migration. Success in choosing new locations depends on many factors beyond the migrant's control. A wrong decision has unfortunate consequences, both for the individual and for the community to which he goes. In many communities migrants are no longer welcome unless they are financially independent. They are regarded as potential liabilities rather than as assets.

Public administration of relief has in general tended to restrict mobility. Few communities are willing to support any but their own residents; hence a specified length of residence is prerequisite to receipt of relief. It is probable that the maintenance of legal residence will become increasingly important in the future as more and more States adopt social security laws, except insofar as this effect may be modified by Federal legislation or interstate agreements. Many of the unemployment insurance systems exclude certain occupations, including agriculture, from their benefits. The extent to which this will affect the mobility of labor cannot be foreseen at present.

. . . The development of a comprehensive Nation-wide system of unemployment registration and exchange may do much to obviate the undesirable consequences of unguided migration, to discourage movements premised on false information, and to facilitate the location of real opportunities corresponding to individual interests and qualifications. The improvement of educational opportunities in areas from which emigration is to be expected may prove even more helpful. (Pp. 117-18)

The economic determinants of demographic metabolism are lightly passed over, however. There is inadequate recognition of the fact that the volume of opportunity-creating interstate and inter-occupational migration is conditioned by the degree of price flexibility, by the extent to which monopolistic arrangements (whether of entrepreneurial or of labor origin) limit the expansion of production and employment and aggravate tendencies to cyclical unemployment.* There is no analysis of the factors making for under-employment equilibrium, and of the influence of under-employment equilibrium upon demographic metabolism. Therefore there is no discussion of the probability, or of the possibility, of demography-affecting economic reforms.

Pious wishfulness, and not attention to the stark cultural realities of the situation, permeates the *Report* comments on measures to check depopulation and to rectify present reproductive trends:

In a civilization in which reproduction, among those enjoying sufficient resources to control family size, is insufficient for population replacement, there is need for establishing conditions more favorable to voluntary formation and adequate support of moderately large families.

The primary need here is for a general recognition of the actual situation. Young people today are influenced by the modern reactions against involuntary reproduction. They are more impressed with the high fertility of their forbears and with the large families of the poor than with the trend toward infertility on the part of those with high school education and moderate incomes. As time goes on, an increasingly large proportion of children will come from parents who have emphasized the values associated with family life and borne a moderately large number of children voluntarily. It is by no means unlikely that there may be a spontaneous reaction toward family security and effective reproduction. It is also possible that public policy may lead to the establishment of economic and cultural conditions that will more effectively reinforce the spontaneous interest of human beings in reproduction and parenthood.

. . . . While there may be much excellence in the family that has its sole *raison d'être* in the companionship of husband and wife and in the one-child or the two-child family, it may be doubted whether such families bring as great emotional satisfaction or afford such full development of personalities as the moderately large family, if the means of support are adequate to provide for such a family at an accepted standard of living. (P. 251)

For the supposition that selective or other chance-governed forces will soon restore reproductive selection to a eugenic level there is little if any warrant or evidence. Such a supposition tends to prevent necessary reforms in precisely the same manner that the suppositions

*See A. R. Burns, *The Decline of Competition*, New York, 1936; F. A. Fetter, *Proceedings of the Academy of Political Science*, May, 1938; also the writer's discussion in *Southern Economic Journal*, October, 1937, pp. 146-53.

that men are genetically equal, and that cultural progress proceeds independently of the genetic composition, check eugenic progress; or that the tendency of the press and the Christian church to play down the implications of differenital selection blocks anti-dysgenic legislation.

The present situation calls for effective governmental action along various lines. First, economic reforms designed to suppress monopoly and to put the allocation of the factors of production on a basis that is competitive or analogous to the competitive are needed; for only under such circumstances can the population become properly distributed geographically and occupationally. Second, reforms suited to reduce cyclically depressive tendencies to a minimum are needed to permit the competitive distribution of population to work out. Third, the state must stand ready to finance the rearing of healthy children with an I.Q. above some designated minimum level (say 110 or 120) whenever and wherever parental incomes are inadequate. Fourth, the state must facilitate the rapid spread of birth control (whether by means of contraception, "safe period," or abortion) into the lower socio-economic classes (particularly among unskilled laborers).

In so far as is consistent with what is now known of the relation of heredity and intelligence, procreators of children with I.Q.'s of less than 85 must be recognized as a danger to our form of government of serious proportions. This might be dramatized by a characterization paralleling the "public enemy" label dear to the heart of G-man Hoover. Such subcultural types must be recognized as a menace to Democracy whose reproductive activities must be drastically curtailed—by voluntary means if possible. (To do this effectively intelligence testing of all young children would be necessary if we are to prevent large progenies of mental problem children arising to plague us too late to take any effective action.) All persons themselves having an I.Q. under 85 would, of course, come in the same category. Measures must be taken to minimize their tendency to become social parasites and they should, of course, be "reproductively eliminated" by humane measures consistent with present mores. Those who oppose the diffusion of birth control or the reasonable extension of sterilization, must be looked upon as potential accessories to the creation of public menaces. The administration of charity, relief, institutionalization, and sterilization must be premised upon the proposition that persons with I.Q.'s under 85 are unsuited to discharge their duties as voter-citizens in a democratic community. Social savings effected through the curtailment of the multiplication of sub-cultural persons will serve to offset in part the cost of the child allowances referred to above. Finally, inasmuch as the passage of appropriate social and economic legislation depends in a large degree upon the intelligence of national legislators and state executives, and inasmuch as present elective requirements neither eliminate the uninformed nor insure the election of men competent to understand the the suggestions of highly trained technical men, it is desirable that the right to run for the public offices in question be limited to persons who have passed tests indicating their possession of the knowledge essential to the complete fulfillment of the duties of the office in question. For if quality can be made to reign in the political field, there is a strong likelihood that respect for quality can be made part of the fabric of folkways and mores.

Very clearly between the lines of the *Report* emerges this major challenge to the Democratic ideal. If Democracy is able to put its biological and cultural house in order with respect to the fundamental problems which are stressed in the *Report*, it may face the future confidently. If measures of the type suggested are not effected we must face the fact, unpalatable as it will very generally be, that the coming of the biological and cultural Dark Ages can be prevented only through the ascent into positions of power, by whatever means necessary, of an élite determined to effect the necessary reforms.

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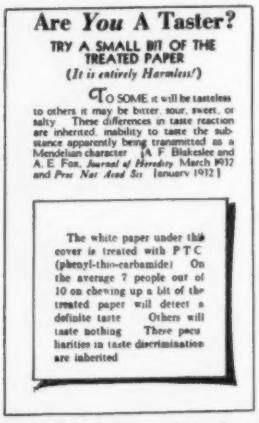
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